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GLOBAL WARMING AND ITS IMPLICATIONS FOR CALIFORNIA

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BEFORE THE

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

FIRST SESSION

ON

GLOBAL WARMING AND ITS IMPLICATIONS FOR CALIFORNIA

SANTA MONICA, CA, MAY 20, 1989

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GLOBAL WARMING AND ITS IMPLICATIONS FOR CALIFORNIA

SATURDAY, MAY 20, 1989

U.S. Senate,
Committee on Energy and Natural Resources,
Santa Monica, CA.

The committee met, pursuant to notice, at 10:15 a.m. in the auditorium, Lincoln Junior High School, Santa Monica, CA, Hon. Timothy E. Wirth, presiding.

OPENING STATEMENT OF HON. TIMOTHY E. WIRTH, U.S. SENATOR FROM COLORADO

Senator **Wirth**. If the Committee might come to order. We want to open by welcoming you all here and thank you very much for coming on such an extraordinarily beautiful day in southern California. If this kind of agenda were on my schedule for the day and I had the discretionary time of not coming, I think that I would be out, probably on the beach somewhere. So, you all are very good to be here. Thank you very much.

I am Senator Tim Wirth from Colorado and have responsibility on the Committee on Energy and Natural Resources in the United States Senate for the issues related to global climate change. I am joined today on my left by somebody familiar to all of you, the senior Senator from California, Senator Alan Cranston, who has been deeply engaged in these issues for a long time and enormously helpful to us all, and on my right by Senator Albert Gore, who has been a leader in this effort for many, many years, long before most Americans had ever heard of the issue of global warming.

Lieutenant Governor Leo McCarthy is also with us this morning. We're glad to have you here, and our home town Congressman, Congressman Mel Levine, who has to head down the road, I know before too long. So, why do we not start, Mel, perhaps with a word of welcome from you. Thank you very much for hosting us here.

STATEMENT OF HON. MEL LEVINE, U.S. REPRESENTATIVE FROM CALIFORNIA

Mr. **Levine**. Well, thank you very much and I am delighted that you have brought this distinguished group here to Santa Monica for such important hearings. I am very privileged to be able to join you for a few minutes and welcome you. And as you indicated, unfortunately, I have a conflicting event about a mile away, where we are trying to again encourage the Bush administration and the Interior Department to once and for all not sink oil wells in places like the Santa Monica Bay and in other sensitive parts of our coast line, issues that you are very familiar with and you have been very helpful to us on.

As somebody who had the privilege of serving with both you and the junior Senator from Tennessee in the House, and who has the privilege of working regularly with our senior Senator and our Lieutenant Governor, I cannot think of a more distinguished group of people to be here and to be focusing on this issue. And I will abstain from making detailed remarks on the merits. I know that you are each going to highlight the critically important issues of global warming and that fact that you, Tim, and you, Al and Alan and Leo have been taking the lead on these issues and making Americans aware of the enormous importance of this issue.

When some of us are wondering what happened to winter in Washington D.C. last winter, for example, and wonder about whether the changes in the climate are really something to be deeply concerned about, and I fear that they are, I'm very, very pleased that you have this hearing here in Santa Monica and that you're having the witnesses that you are. I am sorry I cannot stay longer, but I wanted to be here to welcome you and to salute you for the work that you are doing.

Senator **Wirth**. Mel, thank you very much. I am very pleased to be here. Let me start by just a brief opening statement.

As we all know, this spring California is bracing for the third consecutive year of drought conditions. Pressure is building on the state's water distribution system and as we will learn today, scientists predict that these conditions will occur more frequently as the earth warms in the future. Global warming has emerged as the most vexing environmental, economic and social challenge facing California and the world.

Slowly but steadily, the planet is warming and the climate is changing. In the future, the changes will become in all probability, much more extreme. Nowhere is the magnitude of this threat more clear than here in California. Global warming will effect the coast, the quality and availability of water, the state's agricultural productivity and its air quality. In fact, the foundations of California's economy are at risk.

Consider the effects of global warming on water resources, the life blood of the west in California and in my home state of Colorado. Without elaborate schemes to harness scarce water resources, the arid west might have remained the frontier it once was. Without action to prevent global climate change, today's water management schemes may not work. If we continue to spew carbon dioxide and other greenhouse gases into the atmosphere, the heralded California climate could change dramatically, affecting the precious flow of water to homes, farms and industry.

A recent analysis by the EPA on the effects of climate change estimated the water flows could decrease by an average of 15 percent over the next 50 years. The EPA report found that more precipitation would fall in the state but in a pattern much different from today. In a hotter greenhouse, winter snows would turn to winter rains, increasing the severity of floods while eliminating that natural water storage provided by snow. In short, supplies of water will decrease. Water quality will decline. New environmentally harmful dams will need to be built and agricultural and fishery yields will be slighted.

Most Californians certainly will remember the drought years of a decade ago. At that time, pressures on water resources became severe, water rationing was required and residents of the San Francisco Bay area were drinking water of high salinity. Indeed, the droughts of the last decade may be snapshots of what the future holds.

Unfortunately the economic effects of global warming go beyond questions of water distribution. Decreased snowfall could harm California's robust recreation and tourism industry. The ski industry, for example, as in my home state of Colorado, could be impacted by inadequate snowfall. Critical wildlife habitat, such as wetlands, could be inundated with rising sea levels. And a host of other impacts must be understood and examined as well, from the future of agriculture to the health of forests.

Clearly, this is a future we do not want to confront. The climate is our ally. We base our social and economic institutions on a predictable climate, but the development ushered in at the dawn of the industrial revolution has led to a thicker atmospheric blanket around the planet. During the past hundred and fifty years, our witnesses will show, industrial growth with levels of carbon dioxide, the primary gas, has increased by twenty-five percent. Other gases such as chlorofluorocarbon, methane and tropospheric ozone have been introduced into the skies by man's activities.

As in the past, California may serve as the environmental conscience of this nation and the world. Creative energy efficiency and alternative energy programs have been pioneered here. For example, in the Mohave Desert, Luz International operates a 200 Megawatt solar energy facility, a facility we are going to be visiting on Monday morning, the world's largest. There are tangible examples in California for other state and federal policy makers to see that energy can be produced in an environmental sensitive manner and out front is a van that the public service company has, an electric van, that is soon going to be introduced in southern California, which is available if any of you are interested in seeing how that operates.

But much more work remains to be done. The purposes of today's hearing is to make further the record that we need in the United States Congress in developing appropriate public policy action. We hope that the Committee can obtain information about global warming, what it means for a state like California and what examples this sets for us around the world. It is time to respond to this great challenge and I hope that we will have the support of as many people as possible from this citizen level at all levels of the government, all levels of our society, to put pressure on our government to understand the inexerability of these trends and the fact that we have to get with this right now.

Senator Cranston, let me recognize you for any remarks that you might like to make.

[The prepared statement of Senator Wirth follows:]

Senator Tim Wirth
NEWS RELEASE

U.S. Senate • Washington, D.C. • 20510

STATEMENT OF THE HONORABLE TIMOTHY E. WIRTH

May 20, 1989

This Spring, California is bracing itself for the third consecutive year of drought conditions. Pressure is building on the state's water distribution system. As we will learn today, scientists predict that these conditions will occur more frequently as the Earth warm's in the future. Global warming has emerged as the most vexing environmental, economic and social challenge facing California and the world. Slowly, but steadily the planet is warming and the climate is changing. In the future, the changes will become, in all probability, much more extreme.

Nowhere is the magnitude of this threat more clear than here in California. Global warming will effect the California coast, the quality and availability of water, the state's agricultural productivity and its air quality. In fact, the foundations of the California economy are at risk.

Consider, the effects of global warming on water resources, the lifeblood of the Western United States. Without elaborate schemes to harness scarce water resources, the arid West might have remained the frontier it once was. Without action to prevent global climate change, today's water management schemes may not work.

If we continue to spew carbon dioxide and other "greenhouse" gases into the atmosphere, the heralded California climate could change dramatically -- effecting the precious flow of water to homes, farms and industry. A recent analysis by the Environmental Protection Agency (EPA) on the effects of climate change estimated that water flows could decrease, on average, by 15 percent during the next 50 years. The EPA report found that more precipitation would fall on the state, but in a pattern much different from today. In a hotter greenhouse, winter snows would turn to winter rains -- increasing the severity of floods while eliminating the natural water storage provided by snow. In short, supplies of water will decrease; water quality will decline; new, environmentally harmful dams will need to be built; and agricultural and fishery yields will be slighted.

Most Californians can remember the drought years of 1976-77. At that time, pressures on water resources became severe. Water rationing was required and the residents of the San Francisco Bay area were drinking water of high salinity. Indeed, the droughts of the last decade may be snapshots of what the future holds.

Unfortunately, the economic effects of global warming go beyond questions of water distribution. Decreased snowfall could harm California's robust recreation and tourism industry. The ski industry, for example, could be impacted by inadequate snowfall. Critical wildlife habitat, such as wetlands, could be inundated with rising sea levels.

MORE

And there is a whole host of other impacts that must be examined -- from the future of agriculture to the health of forests.

Clearly, this is a future we do not want to confront: Climate is our ally. We base our social and economic institutions on a predictable climate. But the development ushered in at the dawn of the industrial revolution has led to a thicker atmospheric blanket around the planet.

During the past 150 years of industrial growth, levels of carbon dioxide, the primary greenhouse gas, has increased by 25 percent. Chlorofluorocarbons, methane and tropospheric ozone have been introduced into the skies by man's activities. It is time to halt our assault on the atmosphere and launch a new battle to protect the global environment.

As it has in the past, California may serve as the environmental conscience of this nation and the world. Creative energy efficiency and alternative energy programs have been pioneered here. For example, in the Mohave Desert, Luz, International, operates a 200 Megawatt solar energy facility -- the world's largest. There are tangible examples in California for other state and federal policymakers to see that energy can be produced in an environmentally sensitive manner. We can power a flourishing economy without fouling the global commons. But much more work remains to be done.

The purpose of today's hearing is to begin that process. We hope that the Committee can obtain information about what global warming means to for a state like California. The Committee is also interested in learning more about California's energy and environmental programs. And we have a distinguished panel of witnesses to help us better understand these issues.

It is time now to respond to this great challenge. Governments, from the local to the federal level must act now to reduce greenhouse gas emissions.

Two decades ago, Robert F. Kennedy said: "The future does not belong to those who are content with today, apathetic toward common problems and their fellowman alike, timid and fearful in the face of new ideas and bold projects. Rather, it will belong to those who can blend passion, reason and courage in a personal commitment to the ideals and great enterprises of American society."

Global warming is a new idea and a bold challenge. To protect the economic future of this and every other state, we must be up to the task. Let's get on with it.

# # #

STATEMENT OF HON. ALAN CRANSTON, U.S. SENATOR FROM CALIFORNIA

Senator **Cranston**. Thank you very much, Tim. I want to pay tribute to you for bringing this hearing to our state and I want to pay tribute to you and Al Gore for your leadership on this matter. Only a few Senators are really focusing yet as all too few citizens are yet focusing on the threat of global warming. And two that have been way out front are Tim Wirth and Al Gore and I am very grateful to them. And I think all people in our country and elsewhere should be grateful to them for the leadership they are providing. I am delighted that Mel Levine and Leo McCarthy are playing their part in this in a very vigorous and creative way also.

Let me start a very brief statement by saying pity us poor politicians. We always seem to be the bearer of sad tidings. While millions of Americans are still going around singing last year's hit tune, "Don't Worry, Be Happy', Senators who take their job seriously are constantly bringing people warnings of bad news, trade deficits, housing shortages, inflation, recession, nuclear war and now global warming.

We take on these unhappy tasks in hopes that our warnings will induce people in governments to take steps to avoid catastrophes, such as arms reductions to reduce the danger of nuclear war or to mitigate disasters such as engineering earthquake resistant structures, or to delay catastrophes as long as possible into the far distant future. That is the case with global warming, which is already underway. Already the earth is warmer than scientists predicted it would be just five years ago. And with five of the hottest years thus far, the 1980's is considered to be the hottest recorded decade. With a growing world population, with massive deforestation, with the burning of fossil fuels on a prodigious scale, we have already passed the point of no return.

Scientists tell us that even if all greenhouse gas emissions were stopped today, and they will not be, the planet would still warm by two to four degrees fahrenheit as a result of activities we humans have already engaged in with adverse results we still can only guess at. Since we will not stop today, the increases in temperature will probably exceed four degrees and by the year 2030, the world is apt to be warmer than it has been in the past two million years. Things are already getting worse rapidly.

The atmosphere has fundamentally altered and it will take centuries to return to page equilibrium, if ever. The Environmental Protection Agency warns that California and other coastal states and the world could face a rise in the sea level from anywhere from two to seven feet. The preponderant scientific view is that a sizable rise, will indeed, inevitably occur. It is already started, albeit slowly. This could put millions of acres under water, destroying the value of millions of homes and businesses and agricultural crops and worsening the already terrible effects of air pollution. It could produce millions of new refugees, countries like Bangladesh and elsewhere.

Slowly but surely, fortunately, people in governments are beginning to pay heed. Here in California, we're striving to become less dependent on energy from fossil fuel. We're promoting alternate sources of energy, such as solar, wind, and geothermal. And California citizens and many of their Representatives in Congress are battling against unnecessary oil drilling in the Outer Continental Shelf. Efforts to mobilize a world-wide struggle to halt the human deeds that produced the greenhouse are underway. But the main fight is still ahead of us.

Let me say this in closing. I am convinced that the fight against global warming will be the longest and toughest of any of our environmental battles, far long, far tougher than any we have known, because of its vast cost, because it requires changing so many habits that are inveterate and in many cases profitable, because of inertia, because of the difficulty of getting the public to enlist in a crusade against a threat, no matter how dire, that is neither visible nor remediate, and because it requires the mobilization of so many people and so many governments and so many places around this world. But wage the fight, we must and win it, we must.

Perhaps one transcendental benefit will come out of all this. The whole human race may learn that it must join together in a common struggle to survive. We've begun to learn this lesson in controlling nuclear weapons. Perhaps we will also learn it now in controlling global warming. Thank you, Tim.

Senator **WIRTH**. Thank you very much, Senator Cranston. We are joined this morning by Lieutenant Governor McCarthy.

STATEMENT OF HON. LEO McCARTHY, LIEUTENANT GOVERNOR, STATE OF CALIFORNIA

Mr. **McCARTHY**. Thank you, Mr. Chairman. Let me first applaud you, sir, and Senator Gore for long leadership in the global warming issue, and of course, we look to Senator Cranston in this state as our environmental champion on a range of issues and to Congressman Mel Levine, who is here as well, waging these fights. There will not be any quick dividends for public officials that have the courage to tackle this problem, because nobody is going to be able to send out a press release one or two or three years from now that we have solved this whole problem or even major parts of it. Dealing with this one is going to require a lot of hard work out of the limelight and those who take the lead on it, will have to take on some powerful economic interest who have a huge stake in the status quo.

Those leaders will have to convince the public that in order to preserve our children's and our grandchildren's futures, we are all going to have to make some dramatic and difficult changes in our lifestyles. One of our greatest challenges as public officials, will be to convince the public of the seriousness of this problem. A growing percentage of Americans now see global warming as a serious threat, but it's still a relatively low number. Americans are confronting more immediate environmental problems, pesticides in their food and water, air pollution, toxic waste dumps in their backyard and oil spills on the nightly news.

So, it will not be easy to convince them to pay attention to a problem that may still look like it is fifty to a hundred years off, but we are beginning to detect global warming, thanks to the support and good research by our scientists and by the turn of the century, we now begin to understand we could be feeling real effects.

Today's air pollution is tomorrow's global warming. We are here today because we know the truth, global warming poses a serious threat to all Americans. It will have a real impact. In California, global warming could reduce the amount of water supplied to Los Angeles by seven to sixteen percent while the area's population will have increased by fifty percent. It could cause a one to three meter sea level increase in the San Francisco Bay within fifty years, wiping out billions of dollars of property. It could cause salt water to migrate up to six miles inland in the Sacramento Delta. That would reduce the population of salt water fish that spawn in fresh water, and destroy two billion dollars of farm land.

Global warming could greatly increase the number of Californians exposed to excessive levels of ozone and smog, increasing the number of people who, as a result develop respiratory ailments. It would force us to spend up to $27 billion for new power plants needed to meet increased demand for electricity. California will feel the impact of global warming. That is why we have to act. Congress should start by following Senator Wirth's lead and the lead of his colleagues here, in developing a sensible national energy policy. And I plan to do everything I can, Mr. Chairman, to try to bring California's transportation and energy policies into line with the national policy you are trying to evolve right now.

Global warming is a global warning, make dramatic changes now or face drastic problems later on. It is clear none of us want our kids or our grandchildren to face wide-spread crop damage, flooding or ozone exposure because we would not reduce our use of fossil fuels and chloroflourocarbons. Thank you very much for this opportunity to join you.

Senator WIRTH. Thank you, very much. Senator Gore.

STATEMENT OF HON. ALBERT GORE, U.S. SENATOR FROM TENNESSEE

Senator GORE. Thank you very much, Senator Wirth, Mr. Chairman, Senator Cranston. It is an honor to be with you at the same table with you today. I have appreciated your work on environmental issues and other issues for so long, and as our number two leader in the Senate, we all look to you for leadership. And Leo McCarthy, my good friend, that was a wonderful statement. I am glad to be here with you on this issue and with our witnesses.

Senator Tim Wirth has been an outstanding leader on this issue and he and I have really enjoyed working together with people like Dr. Steve Schneider. I think we have done a whole lot more together than we could have done separately and we talk probably a hundred times a week on these related issues. And this is the most difficult and most serious set of issues that human kind has ever faced. And the first hurdle is realizing that the problem is actually there.

A lot of people dismiss it out of hand feeling that it's kind of like a bad science fiction movie. It just cannot be that the cumulative impact of human civilization could have a bigger effect on the earth's environment than nature itself. That does not seem consistent with our historical experience or our common sense. But we are going to be hearing today specific evidence from the scientists about what the impact of global warming will be right here in California. We have to do this in all parts of the country to awaken people's awareness of why we need to really start immediately with a set of policy responses that are going to be very difficult, but absolutely essential.

We need leadership from the White House, but you know I was reading in one of the newspapers this morning, Alan Cranston, as usual was taking a pro environmental point of view in proposing new protections for a scenic area and President Bush's new Secretary of the Interior, Manuel Lujan has said that this controversial proposal to open up a mine with all the waste piles that are associated with the mine in the middle of this scenic area might be all right if—he thinks that the company's plan to dye the waste a desert color, to give it a natural look might be okay. He says, "I was very impressed with what they say is their reclamation effort, using dye to give it a natural look".

And one of the mining company officials says, "I think this Secretary of the Interior is going to be better than anyone we have ever had". He said, "He seems like he is all man". Well, it seems to me that that is kind of crazy. Next, this administration may propose painting New York City's garbage barge sea green or dying the smog blue or trying to paint Prince William Sound back to its natural color.

It's kind of a tune town environmentalist, whatever you need, you take out the pallet and paint it. But really the solutions are going to be a lot more difficult than what they now are even thinking about. Global climate change, destruction of the stratospheric ozone layer and a host of other related problems, are going to require the kind of tough day to day work that our witnesses are doing and are going to be telling us about. And they are inter-related.

For example, yesterday in the United States Senate, we had hearings on some legislation to try to protect the stratospheric ozone layer. Let me use that as an example to describe the interconnections. The chemicals that destroy the stratospheric ozone layer, CFC's, are also responsible to 20 percent of the greenhouse effect. So, those two problems are related.

Second relationship, when the stratospheric ozone layer is thinned out, more ultra-violet radiation comes down to the ground level and interacts with the exhaust fumes of automobiles and the low level ozone or smog problem here in Los Angeles gets worse. So, the less ozone we have in the stratosphere, the more global warming and the more smog we have in our large cities. In fact, there are a lot of cities in America that will not ever be able to meet the compliance standards on low level ozone unless we do something about the extra ultra-violet radiation that is coming in through the stratosphere. So, these problems are related.

And as we will learn in the hearing today, we need legislation. I am very proud to have Senator Wirth as a co-sponsor of the bill that I introduced and proud to be a co-sponsor of the bill that he introduced. And we have both benefited from the advice and counsel of Senator Cranston. I am going to skip the rest of the oral presentation of my statement and put it in the record, Mr. Chairman, but let me just close by saying that I think we have to start looking at global climate change as a national security issue. We are threatened, our children are threatened, our world is threatened, our nation is threatened by these global environmental problems just as we used to feel the threats principally from the Soviet Union.

The U-2 spy plane is not looking at missile silos now. It is looking at the ozone hole. In southern Iowa, the National Guard troops have been called out, not to use their guns, but to deliver drinking water to areas that have not had rain for over a year. Just as when we are threatened in our national security, and feel our survival is at stake, we sometimes think about drastic responses. We have to start thinking about the possibility of drastic responses where global environmental change is concerned.

We cannot continue just letting things go on the way they are going on now. If we do that, then our world will be a more hostile place for our children and grandchildren. We have to face up to it. And this hearing is an essential part of a whole series of efforts to try to organize an intelligent response. So, I will put the rest of my statement in the record, Mr. Chairman. I am glad to be here and look forward to the hearing.

[Material submitted for the record by Senator Gore follows:]

The Washington Post

OUTLOOK

Commentary and Opinion

[illegible] FOR THE WASHINGTON POST

Our Global Eco-Blindness

Earth's Fate Is the No. 1 National Security Issue

By Al Gore

HOW CAN WE possibly explain the mistakes and false starts President Bush has been making on environmental policy? His administration's decision to censor scientific testimony on the seriousness of the greenhouse effect—and initially to oppose an international convention to begin working out a solution to it—may well mean that the president himself does not yet see the threat clearly. Apparently he does not hear the alarms that are awakening so many other leaders from Margaret Thatcher to Mikhail Gorbachev.

Humankind has suddenly entered into a brand new relationship with the planet Earth. The world's forests are being destroyed; an enormous hole is opening in the ozone layer. Living species are dying at an unprecedented rate. Chemical wastes, in growing volumes, are seeping downward to poison groundwater while huge quantities of carbon dioxide, methane and chlorofluorocarbons are trapping heat in the atmosphere and raising global temperatures.

How much information is needed by the human mind to recognize a pattern? How much more is needed by the body politic to justify action in response?

If an individual or a nation is accustomed to looking at the future one year at a time, and the past in terms of a single lifetime, then many large patterns are concealed. But seen in historical perspective, it is clear that dozens of destructive effects have followed the same pattern of unprecedented acceleration in the latter half of the 20th century. It took 10,000 human lifetimes for the population to reach 2 billion. Now in the course of one lifetime, yours and mine, it is rocketing from 2 billion to 10 billion, and is already halfway there.

Yet, the pattern of our politics remains remarkably unchanged. That indifference must end. As a nation and a government, we must see that America's future is inextricably tied to the fate of the globe. In effect, the environment is becoming a matter of national security—an issue that directly and imminently menaces the interests of the state or the welfare of the people.

To date, the national-security agenda has been dominated by issues of military security, embedded in the context of global struggle between the United States and the Soviet Union—a struggle often waged through distant surrogates, but which has always harbored the risk of direct confrontation and nuclear war. Given the recent changes in Soviet behavior, there is growing optimism that this long, dark period may be passing. This may in turn open the international agenda for other urgent matters and for the release of enormous resources, now committed to war, toward other objectives. Many of us hope that the global environment will be the new dominant concern.

Of course, this national-security analogy must be used very cautiously. The U.S.-Soviet rivalry has lasted almost half a century, consumed several trillions of dollars, cost close to 100,000 American lives in Korea and Vietnam and profoundly shaped our psychological and social consciousness. Much the same could be said of the Soviets. Nothing relieves us of our present responsibilities for defense or of the need to conduct painstaking negotiations to limit arms and reduce the risk of war.

And yet, there is strong evidence the new enemy is at least as real as the old. For the general public, the shocking images of last year's drought, or of beaches covered with medical garbage, inspired a sense of peril once sparked only by Soviet behavior. The U2 spy plane now is used to monitor not missile silos but ozone depletion. Every day in parts of southern Iowa, where it hasn't rained for more than a year, National Guard troops are being used to distribute drinking water. In the not too distant future, policies that enable the rescue of the global environment will join, perhaps even supplant, our concern with preventing nuclear war as the principal test of statecraft.

However, it is important to distinguish what would—in military jargon—be called the level of threat. Certain environmental problems may be important but are essentially local; others cross borders, and in effect represent theaters of operations; still others are global and strategic. On this scale, the slow suffocation of Mexico City, the deaths of forests in America and Europe or even the desertification of large areas of Africa might not not be regarded as full-scale national-security issues. But the greenhouse effect and stratospheric ozone depletion *do* fit the profile of strategic national-security issues.

When nations perceive that they are threatened at the strategic level, they may be induced to think of drastic responses, involving sharp discontinuities from everyday approaches to policy. In military terms, this is the point when the United States begins to think of invoking nuclear weapons. The global environment crisis may demand responses that are comparatively radical.

At present, despite some progress made toward limiting some sources of the problem, such as CFCs, we have barely scratched the surface. Even if all other elements of the problem are solved, a major threat is still posed by emissions of carbon dioxide, the exhaling breath of the industrial culture upon which our civilization rests. The implications of the latest and best studies on this matter are staggering. Essentially, they tell us that with our current pattern of technology and production, we face a choice between economic growth in the near term and massive environmental disorder as the subsequent penalty.

This central fact suggests that the notion of environmentally sustainable development at present may be an oxymoron, rather than a realistic objective. It declares war, in effect, on routine life in the advanced industrial societies. And—central to the outcome of the entire struggle to restore global environmental balance—it declares war on the Third World.

If the Third World does not develop economically, poverty, hunger and disease will consume entire populations. Rapid economic growth is a life-or-death imperative. And why should they accept what we, manifestly, will not accept for ourselves? Will any nation in the developed world accept serious compromises in levels of comfort for the sake of global environmental balance? Who will apportion these sacrifices; who will bear them?

The effort to solve the nuclear arms race has been complicated not only by simplistic stereotypes of the enemy and the threat he poses, but by simplistic demands for immediate unilateral disarmament.

Similarly, the effort to solve the global environmental crisis will be complicated not only by blind assertions that more environmental manipulation and more resource extraction are essential for economic growth. It will also be complicated by the emergence of simplistic demands that development, or technology itself, must be stopped for the problem to be solved. This is a crisis of confidence which must be addressed.

Al Gore is a Democratic senator from Tennessee.

The tension between the imperatives of growth and the imperative of environmental management represents a supreme test for modern industrial civilization and an extreme demand upon technology. It will call for the environmental equivalent of the Strategic Defense Initiative: a Strategic Environment Initiative.

I have been an opponent of the military SDI. But even opponents of SDI recognize this effort has been remarkably successful in drawing together previously disconnected government programs, in stimulating development of new technologies and in forcing a new analysis of subjects previously thought exhausted.

We need the same kind of focus and intensity, and similar levels of funding, to deal comprehensively with global warming, stratospheric ozone depletion, species loss, deforestation, ocean pollution, acid rain, air and water and groundwater pollution. In every major sector of economic activity a Strategic Environment Initiative must identify and then spread increasingly effective new technologies: some that are already in hand, some that need further work, and some that are revolutionary ideas whose very existence is now a matter of speculation.

For example, energy is the life blood of development. Unfortunately, today's most economical technologies for converting energy resources into useable forms of power (such as burning coal to make electricity) release a plethora of pollutants. An Energy SEI should focus on producing energy for development without compromising the environment. Priorities for the near term are efficiency and conservation; for the mid-term, solar power, possibly new-generation nuclear power, and biomass sources (with no extraneous pollutants and a closed carbon cycle); and for the long term, nuclear fusion, as well as enhanced versions of developing technologies.

In agriculture, we have witnessed vast growth in Third World food production through the Green Revolution, but often that growth relied on heavily subsidized fertilizers, pesticides, irrigation and mechanization, sometimes giving the advantage to rich farmers over poor ones. We need a second green revolution, to address the needs of the Third World's poor: a focus on increasing productivity from small farms on marginal land with low-input agricultural methods. These technologies, which include financial and political components, may be the key to satisfying the land hunger of the disadvantaged and the desperate who are slashing daily into the rain forest of Amazonia. It may also be the key to arresting the desertification of sub-Saharan Africa, where human need and climate stress now operate in a deadly partnership.

Needed in the United States probably more than anywhere is a Transportation SEI focusing in the near term on improving the mileage standards of our vehicles, and encouraging and enabling Americans to drive less. In the mid-term come questions of alternative fuels, such as biomass-based liquids or electricity. Later will come the inescapable need for re-examining the entire structure of our transportation sector, with its inherent emphasis on the personal vehicle. The U.S. government should organize itself to finance the export of energy-efficient systems and renewable energy sources. That means preferential lending arrangements through the Export-Import Bank, and Overseas Private Investment Corporation.

Encouragement for the Third World should also come in the form of attractive international credit arrangements for energy-efficient and environmentally sustainable processes. Funds could be generated by institutions such as the World Bank, which, in the course of debt swapping, might dedicate new funds to the purchase of more environmentally sound technologies.

Finally, the United States, other developers of new technology, and international lending institutions, should establish centers of training at locations around the world to create a core of environmentally educated planners and technicians—an effort not unlike that which produced agricultural research centers during the Green Revolution.

Immediately, we should undertake an urgent effort to obtain massive quantities of information about the global processes now under way—through, for example, the Mission to Planet Earth program of NASA.

And we also must target first the most readily identifiable and correctable sources of environmental damage. I have introduced a comprehensive legislative package that incorporates the major elements of this SEI: It calls for a ban, within five years, on CFCs and other ozone-depleting chemicals, while promoting development of safer alternatives; radically reducing CO2 emissions and increasing fuel efficiency; encouraging massive reforestation programs; and initiating comprehensive recycling efforts.

Although Congress is recognizing the challenge, there remains a critical need for presidential leadership, for President Bush to show that as a nation we have the vision and the courage to act responsibly. And in order to accomplish our goal, we also must transform global politics, shifting from short-term concerns to long-term goals, from conflict to cooperation. But we must also transform ourselves—or at least the way we think about ourselves, our children and our future. The solutions we seek will be found in a new faith in the future of life on earth after our own, a faith in the future which justifies sacrifices in the present, a new moral courage to choose higher values in the conduct of human affairs, and a new reverence for absolute principles that can serve as guiding stars for the future course of our species and our place within creation.

An Ecological Kristallnacht. Listen.

By Albert Gore Jr.

WASHINGTON

Humankind has suddenly entered into a brand new relationship with our planet. Unless we quickly and profoundly change the course of our civilization, we face an immediate and grave danger of destroying the worldwide ecological system that sustains life as we know it.

It is time to confront this danger.

In 1939, as clouds of war gathered over Europe, many refused to recognize what was about to happen. No one could imagine a Holocaust, even after shattered glass had filled the streets on Kristallnacht. World leaders waffled and waited, hoping that Hitler was not what he seemed, that world war could be avoided. Later, when aerial photographs revealed death camps, many pretended not to see. Even now, many fail to acknowledge that our victory was not only over Nazism but also over dark forces deep within us.

In 1989, clouds of a different sort signal an environmental holocaust without precedent. Once again, world leaders waffle, hoping the danger will dissipate. Yet today the evidence is as clear as the sounds of glass shattering in Berlin.

Listen:

- The earth's forests are being destroyed at the rate of one football field's worth every second, one Tennessee's worth every year.
- An enormous hole is opening in the ozone layer, reducing the earth's ability to protect life from deadly ultraviolet radiation.
- Living species die at such an unprecedented rate that more than half may disappear within our lifetimes.
- Chemical wastes, in growing volumes, seep downward to poison ground water and upward to destroy the atmosphere's delicate balance.
- Huge quantities of carbon dioxide, methane and chlorofluorocarbons dumped in the atmosphere have trapped heat and raised global temperatures.
- Every day, 37,000 children under the age of 5 die of starvation or preventable diseases made worse by failures of crops and politics.

Why are these dramatic changes taking place? Because the human population is surging; (it took a million years to reach two billion people. In the last 40 years, world population has doubled. And in the next 40 years, the number of people could double again); because the industrial, scientific and technological revolutions magnify the environmental impact of these increases, and because we tolerate self-destructive behavior and environmental vandalism on a global scale.

Why, once again, do we fail to rally our forces? Much of the world closed its eyes as Hitler marched because the only adequate response was a horrible war many hoped to avoid. Do we now shrink from the unimaginably difficult response demanded by the global environmental crisis, and hope against hope that it will yet prove unnecessary?

This crisis is so different from anything before that it is hard to believe it is real. We seize scientific uncertainties, however small, as excuses for inaction. Some, like Prime Minister Neville Chamberlain in Munich, would rather adapt to the threat than confront it. This time, they are protected not by an umbrella but by floppy hats and sunglasses.

Our complacency stems in part from a standard of living dependent on rapid consumption of the earth's resources. Our generation has inherited the idea that we have the right to appropriate for ourselves the earth's accumulated treasures as quickly as we can consume them. We reach back through millions of years for the deposits that fuel our industrial civilization.

Just as a drug addict needs increasing doses to produce the same effect, our global appetite for the earth's abundance grows each year. We transform the resources of the past into the pollution of the future, telescoping time for self-indulgence in the present.

In 1987, carbon dioxide levels in the atmosphere began to surge with record annual increases. Global temperatures are also climbing: 1987 was the second hottest year on record; 1988 was the hottest. Scientists now predict our current course will raise world temperatures five degrees Celsius in our lifetimes. The last time there was such a shift, it was five degrees colder; New York City was under one kilometer of ice. If five degrees colder over thousands of years produces an ice age, what could five degrees warmer produce in a lifetime?

In a classic experiment, a frog dropped in boiling water jumps out. The same frog, put in the water before it is slowly boiled, remains in the pot. Our environment is at the boiling point. Will we react?

The 1990's are the decade of decision. Profound changes are required. We must create a new global compact for sustainable development — for example, trading debts for shared environmental stewardship. Our agenda must include the following:

- A worldwide ban in five years on chlorofluorocarbons, which simultaneously destroy the protective ozone layer and cause up to 20 percent of global warming.
- Rapid reductions in carbon dioxide emissions, through increased vehicle mileage standards, increased energy efficiency and development of alternative energy sources.
- A global halt to destruction of forests and swift implementation of worldwide reforestation programs.
- A ban within five years on packaging that is neither recyclable nor naturally degradable, a comprehensive waste minimization program and aggressive efforts to control emissions of methane from landfills and other sources.
- A series of global summit meetings to seek the unprecedented international cooperation the environmental crisis will demand.

In the 1940's, as victory neared over the dark forces unleashed on Kristallnacht, Gen. Omar Bradley offered advice that is once again relevant to the challenge that confronts humanity: "It is time we steered by the stars, not by the lights of each passing ship." □

Albert Gore Jr., a Democrat, is Senator from Tennessee.

ENVIRONMENTAL AND POPULATION CHANGE WORLDWIDE

NEWS FROM

U.S. Senator Al Gore

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FOR RELEASE UPON DELIVERY
11 A - M Monday, May 1, 1989

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GORE ANNOUNCES STRATEGIC ENVIRONMENT INITIATIVE, OZONE LAYER PROTECTION PACKAGE

Bills on Consumer Products, Five-Year CFC Phase-out, Trust Fund

WASHINGTON -- Consumer products that release chemicals destroying the earth's ozone shield -- from automobile air conditioners to noise horns and certain fire extinguishers -- would be labeled, regulated, and nonessential uses would eventually be phased-out under legislation to be introduced today (5/1) by Sen. Al Gore, D-TN.

Gore, who tonight will announce a new Strategic Environment Initiative in a keynote address at the National Academy of Sciences, also will introduce legislation for a phase-out, within five years, of the most dangerous ozone-destroying chemicals and to impose a manufacturers excise tax on ozone-destroying chemicals. Revenues would create an Ozone Layer Conservation Trust Fund to support efforts to find alternatives to those chemicals. This legislation compliments the World Environment Policy Act (S.201) Gore introduced on January 25, the first day of official Senate business.

"We know these chemicals are ripping up the earth's protective ozone layer and contributing to the greenhouse effect. We know that if we immediately stopped all use, the problems they've already created would linger for decades. Hesitation simply cannot be tolerated. We must move as quickly as possible to stop the destruction," said Gore.

"As we work for tougher international agreements for the longer term, there are simple, common sense solutions we can apply now, every day," said Gore. "For example, changing the way we service automobile air conditioners, labeling and eventually stopping the production of non-essential consumer products such as noise horns or party streamers or certain cleaning fluids. I'm also asking the Environmental Protection Agency to design and examine a deposit fee, similar to a 'bottle bill' for chlorofluorocarbons."

(MORE)

Gore's legislation is being introduced as countries participating in the Montreal Protocol, an international agreement to control ozone-depleting chemicals, prepare to open meetings Tuesday (5/2) in Helsinki, Finland.

"There are urgent international enviromental problems that must be addressed, concerning not only the ozone layer, but a broad range of issues," said Gore. "We face unprecedented challenges that we must recognize and confront intelligently, agressively, and in concert with other nations around the world. Leadership from the United States can serve as a catalyst for broader action."

Tonight (5/1), Gore will outline a new Strategic Environment Initiative when he delivers the keynote speech to participants in the Forum on Global Change and Our Common Future at the National Academy of Sciences.

"My purpose is to sound an alarm loudly and clearly -- of imminent and grave danger -- and to describe a strategy for confronting this crisis with changes in our collective behavior and thinking which, if made, can forestall and prevent the horrendous prospect of an ecological collapse," Gore said.

Gore will introduce three separate bills today: The Consumer Ozone Protection Act of 1989; The Ozone Layer Conservation Act of 1989; and The Upper-Ozone Chemicals Act of 1989. These three bills will:

<Develop regulations for servicing automobile air conditioners;

<Label and eventually eliminate sales of small CFC recharge canisters, halon fire extinguishers (for some consumer applications), and non-essential CFC-containing consumer products (e.g. party streamers, noise horns, some cleaning fluids);

<Start an EPA study of a CFC deposit fee to encourage recapture and recycling;

<Amend the Internal Revenue Code of 1986 to impose a manufacturer's excise tax on chemicals which deplete the ozone layer;

<Establish an Ozone Layer Conservation Trust Fund, to receive one-half of the revenues from the excise tax, and promote government-industry cooperation in the research, development, and deployment of technological and chemical alternatives to ozone-depleting chemicals;

<Phase-out, within five years, production of CFC-11, CFC-12, CFC-113, halon-1211, halon 1301, and carbon tetrachloride;

<Establish a safe alternatives policy for replacing the phased-out substances.

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NEWS FROM

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FOR IMMEDIATE RELEASE

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WEDNESDAY, January 25, 1989

GORE INTRODUCES WORLD ENVIRONMENT POLICY ACT OF 1989
CO2 Reductions, CFC Phase-out, Recycling, Biodiversity

WASHINGTON, D.C. -- Calling for a new "international alliance for environmental progress," U.S. Sen. Al Gore, D-TN, is proposing a comprehensive environmental protection bill designed to confront the causes of the greenhouse effect, prevent future environmental damage, and promote global cooperation on these issues.

"We need an international alliance for environmental progress to take its place alongside other alliances that exist in the name of security, recognizing that the threats we face transcend national boundaries and ideology," Gore said. "This bill sets ambitious new targets for a cleaner, safer world. These proposals have a dual purpose, to protect our environment and to employ economic common sense in that job."

Gore, who visited Antarctica and the Amazon rainforests during the Congressional recess, said he chose to introduce this bill on the first day of official business for the 101st Congress to emphasize the importance and the urgency of these issues.

"This summer's news was heavy with our pollution problems, thought-provoking stories that put familiar problems in a far more urgent context," he said. "As we look to the future, we must make the memories of last summer a call to action. We must make these issues our highest priorities and preserve for them not only a place on our agenda but a spot at the top of our agenda."

The World Environment Policy Act of 1989 Gore is introducing contains 10 titles addressing a broad range of issues.

"This bill will help us develop national and international policy responses to world environmental problems. It will provide meaningful controls on the chemicals and gases destroying the ozone shield. It will present a comprehensive plan to promote recycling and dramatically reduce the wastes now crowding and closing our landfills," Gore said. "And, it will provide new, innovative efforts to promote reforestation, preserve the biological diversity of our world, and, confront the very real problems of overpopulation."

(MORE)

Key elements of the bill include:

**Replacing the Council on Environmental Quality with a new Council on World Environmental Policy better able to link scientists' research with policy makers' plans and to introduce into that process a global perspective;
**A complete phaseout of the production of chloroflourocarbons;
**Improvements in fuel economy standards for passenger cars and light trucks;
**A five-year phase-out of non-recyclable packaging to prohibit, five years after enactment, the production of any packaging that cannot be recycled or is not naturally degradable;
**A national policy for the conservation of biological diversity;
**A phased-in ban on imports of tropical wood products not obtained from regimes of sustained yield management
**A proposal that the U.S. Secretary of State propose to the Government of Brazil that the Brazilians take the lead in protecting the Amazon Basin by convening a conference focused on identifying programs to conserve the Basin's resources; the bill also includes a finding that the major industrial nations should be prepared to consider substantial material contributions toward that end.

"This bill is intentionally comprehensive and far reaching," Gore said. "Just as the environmental fate and future of our nation is tied to those of every other nation, so too are these issues tied to each other and to the resolution of the problems we face here and around the globe."

"There is a vital and important connection between the rainforests of Brazil, the frozen wilderness of Antarctica and the natural resources we all enjoy in our home states," Gore said. " That connection is our future, our quality of life today, and our children's quality of life tomorrow. We must recognize that connection and act now."

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NEWS FROM

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FOR IMMEDIATE RELEASE
May 1, 1989

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Remarks of
U.S. SEN. AL GORE
D-Tennessee
Forum on Global Change and Our Common Future
National Academy of Sciences
Washington, D.C.
May 1, 1989

Many of us have come to this gathering because of a shared belief that humankind has suddenly entered into a brand new relationship with the planet Earth, and that human civilization is, in its current pattern, causing grave and perhaps soon irreparable damage to the ecological system which supports life as we know it.

My purpose is to sound an alarm loudly and clearly -- of imminent and grave danger -- and to describe a strategy for confronting this crisis, with changes in our collective behavior and thinking which, if made, can forestall and prevent the horrendous prospect of an ecological collapse.

First, why is such an alarm necessary? Do we need a crisis before we can act?

Sometimes in human affairs a pattern is well set before its implications are felt in our daily lives. This is true both in politics and in science. When shattered glass filled the streets of Berlin on Kristallnacht, few could conceive of the holocaust to follow. But from a distance, the pattern is now clear. When the first atom was split, few could conceive of nuclear bombs. But when Einstein wrote Roosevelt, the pattern was clear.

How much information is needed by the human mind to recognize a pattern? How much more is needed by the body politic to justify action in response?

It took took a long time for the world to respond to Hitler. Because of Hitler, it took only a short time for Roosevelt to respond to Einstein.

In a classic experiment often cited, a frog dropped into a pot of boiling water quickly jumps out. But the same frog, put in the water before it is slowly heated, will remain in place until it is boiled.

The meaning of a pattern is conveyed by contrast as opposed to sameness. Sameness lulls the senses and conveys an absence of danger. Gradual change sometimes resembles sameness, obscuring danger from minds which reserve their alertness for sharp contrasts. Exponential change at first resembles sameness, then gradual change, then explosive contrast.

It is often hard to recognize the shape of an exponential curve before it reaches the explosive stage. It is difficult because the contrast essential to understanding very large patterns is sometimes visible only from a distance.

If an individual or a nation is accustomed to looking at the future one year at a time, and the past in terms of a single lifetime, then many large patterns are concealed. If a political body looks at policies in the context of a single nation, then the global impacts will remain invisible.

When you consider the relationship of the human species to the planet Earth, not much change is visible in a single year, in a single nation. Yet, if you look at the entire pattern of that relationship from the emergence of the species until today, May Day 1989, a distinctive contrast in very recent times clearly conveys the danger to which we must respond. It took ten thousand human lifetimes for the population to reach two billion. Now, in the course of a single human lifetime -- mine and yours -- it is rocketing from two billion toward ten billion, and is already halfway there.

Startling graphs showing the loss of forest land, topsoil, stratospheric ozone, and species all follow the same pattern of sudden, unprecedented acceleration in the latter half of the 20th century. And yet, so far, the pattern of our politics remains remarkably unchanged.

The earth's forests are being destroyed at the rate of one football field's worth every second, one Tennessee's worth every year. An enormous hole is opening in the ozone layer, reducing the earth's ability to protect life from deadly ultraviolet radiation. Living species die at such an unprecedented rate that more than half may disappear within our lifetimes. Chemical wastes, in growing volumes, seep downward to poison groundwater and upward to destroy the atmosphere's delicate balance. Huge quantities of carbon dioxide, methane, and chlorofluorocarbons dumped in the atmosphere are trapping heat and raising global temperatures.

In 1987, carbon dioxide levels in the atmosphere began to surge with record annual increases. Global temperatures are also climbing: 1987 was the second hottest year on record; 1988 was the hottest. Scientists now predict our current course may raise world temperatures almost five degrees Celsius in the lifetimes of people in this room. The last time there was such a shift, it was five degrees colder: New York City was under one kilometer of ice. If five degrees colder over thousands of years produces an ice age, what could five degrees warmer produce in one lifetime?

Why are these dramatic changes taking place? Because the human population is surging, because the industrial, scientific, and technological revolutions magnify the environmental impact of these increases, and because we tolerate self-destructive behavior and environmental vandalism on a global scale.

The problem in organizing our response is that the worst effects seem far off in the future, and they are so unprecedented they seem to defy common sense. While right now, in the present, millions of people are suffering in poverty and dying of starvation, warfare, and preventable diseases. How do we deal with these immediate problems and at the same time confront the problems of the future? One of the philosophers of the environmental movement, Ivan Illich, in a recent interview, explained the sudden environmental activism of Margaret Thatcher, Mikhail Gorbachev, and other world leaders previously uninterested in the global environment by saying "what has changed is that our common sense has begun searching for a language to speak about the shadow our future throws."

Science already has such a language. Have you ever seen the picture showing how time and space are shaped by mass, with a black hole pictured as a deep well in a grid, with the space and time around the well sloping toward it? Human political awareness is shaped by history in precisely that way. Our political awareness of the world is shaped and bent by events. Large events like World War II exert a powerful gravitational pull on every idea we have about the world around us. The Holocaust shapes every idea we have about human nature.

And just as in Einstein's theory, future events can exert the same gravitational pull on our thinking as events in the past -- even though the events in the future have not yet occurred.

Time is relative in politics as in science. The political will which made possible the mass political protests against escalating the nuclear arms race came from awareness of a downslope toward a future we did not want to see. Many felt us being pulled toward a nuclear war that would crush human history forever into a black hole. We are now changing our course away from that downslope, we hope, and taking a new direction -- even though 99.99% of all human beings on earth have never seen, heard, or personally felt nuclear destruction. The awareness of that potential future event came from political communication, with abstract symbols, like words.

Now, throughout the world, we are witnessing the emergence of a new political will to take a different course in order to avoid the slope toward global environmental destruction. We see the catastrophe coming, we hear Rachel Carson's Silent Spring. The slope seemed gradual at first but now it is steep. We feel strongly pulled toward ecological collapse by the policies we are now pursuing.

I personally became deeply involved in the effort to avoid a nuclear holocaust nine years ago because I felt the slope toward that horrendous possibility. And I tried to bring to the task the skills of my profession. I believe all this talk about the global environment as a national security issue makes a great deal of sense in political terms.

For the past 13 years, as a citizen and as a member of the United States Congress, I have had long-standing interests in both the environmental threat and in national security. As a practical matter, I have dealt with these subjects as separate intellectual accounts: involving distinct areas of public policy, each with its own completely different set of concerns and participants.

Yet, they grow more and more alike. National security comprises matters that directly and imminently menace the interests of the state, or the welfare of the people. As such, these issues command the attention of political leaders at the highest level, with a proportionate claim on the resources of government and the wealth of the nation. If society were an organism, national security would involve the instinct for survival.

To this point, the national security agenda has been dominated by issues of military security, embedded in the context of global struggle between the United States and the Soviet Union: a struggle which the protagonists have often waged through distant surrogates, but which has always harbored the risk of direct confrontation and nuclear war.

Given the changes in Soviet behavior which have begun under Gorbachev, there is growing optimism that this long, dark period may be passing. There is also hope this will open the international agenda for other urgent matters and for the release of enormous resources, now committed to war, toward other objectives.

Many hope that the global environment will be the new Dominant Issue. They assert that a collective, international struggle for stability in the ecosystem will succeed the old pattern of national struggle for temporal power, and will justify the preemption of enormous resources, and reshape the public consciousness in support of another long, global struggle.

I am deeply in sympathy with this view, and yet as someone who has worked hard on both issues, I believe the analogy must be used very cautiously. The US-Soviet struggle has lasted almost half a century, consumed several trillions of dollars, cost us close to one hundred thousand American lives in Korea and Vietnam, and has profoundly shaped the psychological and social consciousness of our people. Much the same could be said of the Soviets, who, if anything, have endured far more than have we for the sake of their ideology.

Nothing is automatic or foreordained about the course of US-Soviet relations, no matter how many editorial writers now claim the "Cold War is Over." Nothing relieves us of our present responsibilities for defense or of the need to conduct painstaking negotiations to limit arms and reduce the risk of war. The old agenda is with us still, exacting its price in wealth, creativity and the attention of statesmen.

And yet, the environmentalists are right.

Certainly, there is strong evidence the new enemy is at least as real as the old. For the general public, the shocking images of last year's drought, or of beaches covered with medical garbage, inspired a sense of peril once sparked only by Soviet behavior. But for environmental specialists, the steady flow of data from scientific investigation of the environment -- often ambiguous, but always menacing -- is eerily equivalent to intelligence collection against the more familiar Soviet threat. The U2 spy plane, for example, now is used to monitor not missile silos but ozone depletion.

Already, we are seeing governments struggling to resolve issues whose domains go far beyond anything in our experience. Debate over the disposition of radioactive wastes, for example, involves choices that must remain valid across geological time. The species now disappearing at an unprecedented rate will never return. The global climate pattern could shift to a new equilibrium and never regain its former pattern.

In the not distant future, there will be a new "sacred agenda" in international affairs: policies that enable the rescue of the global environment. This task will one day join, and then perhaps even supplant, preventing the world's incineration through nuclear war, as the principle test of statecraft.

However, in thinking about environmentalism as a national security concern, it is important to differentiate between what would -- in military jargon -- be called the level of threat. Certain environmental problems may be important but are essentially local; others cross borders, and in effect represent theaters of operations; and still others are global and strategic in nature.

On this scale, even phenomena as important as the slow suffocation of Mexico City, the deaths of northern forests in America and Europe, or even the desertification of large areas of Africa, will likely not be regarded as full scale national security issues.

However, the greenhouse effect and stratospheric ozone depletion fit the profile of national security issues of global significance. These phenomena certainly will in time produce effects big enough to threaten international order, even at the level of war and peace. In the case of global warming, the fact that some of the worst effects will not fully manifest themselves until the middle of the next century is offset by the fact that actions we take now will determine the extent of the damage later.

When nations perceive that they are threatened at the strategic level, they may be induced to think of drastic responses, involving sharp discontinuities from everyday approaches to policy. In military terms, this is the point when the United States begins to think of invoking nuclear weapons. The global environment may well involve responses that are, in comparative terms, just as radical. Not just business as usual, not just incremental variations but massive departures from the norm.

Nuclear war is an apocalyptic subject, and so is global environmental destruction. We are dealing here with increasingly credible forecasts of climatic dislocations, vast changes in growing cycles, innundations of coastal areas and the loss to the sea of vast territories -- some of them very heavily developed and populated. We also are dealing not only with a threat to human health, but unpredictable and potentially vast changes to all life at the surface of the earth and the seas, as the result of prolonged exposure to increased ultra-violet radiation.

What's more, despite some progress made toward limiting some sources of the problem, such as CFCs, we have to face the stark fact that we have barely scratched the surface. Even if all other elements of the problem are solved, a major threat is still posed by emissions of carbon dioxide, the exhaling breath of the industrial culture upon which our civilization rests. The implications of the latest and best studies on this matter are staggering. We must be honest about them. Essentially, they tell us that with our current pattern of technology and production, we face a Hobsian Choice between economic growth in the near term, and massive environmental disorder as the subsequent penalty.

This central fact cuts across the face of all environmental strategies as we generally think of them. It suggests that the notion of environmentally sustainable development at present may be an oxymoron, rather than a realistic objective. It declares war, in effect, on routine life in the advanced industrial societies. And -- central to the outcome of the entire struggle to restore global environmental balance -- it declares war on the Third World.

The Third World does not have a choice about whether or not it will develop economically. If it does not develop economically, poverty, hunger and disease will consume entire populations. And long before that, whole societies will experience revolutionary political disorder. Rapid economic growth is a life-or-death imperative throughout the Third World. The peoples and governments of the Third World will not be denied that hope, no matter the longer-term costs for the global environment.

And why should they accept what we, manifestly, will not accept for ourselves? Who is so bold as to say that any nation in the developed world is prepared to abandon industrial and economic growth? Who will proclaim that any nation in the developed world will accept even serious compromises in levels of comfort, for the sake of global environmental balance? And who will apportion these sacrifices; who will then bear them?

Development, of course, is part of the problem as well as the solution. We know that, just as we know that nuclear deterrence depends on the weapons we are trying to render obsolete.

The effort to solve the nuclear arms race has been complicated not only by simplistic stereotypes of the enemy and the threat he poses. It also has been complicated by simplistic demands for immediate unilateral disarmament, without any basis for a widely shared confidence that the original threat is no longer real.

My own belief is that perceptions must evolve simultaneously in both superpowers as technology evolves simultaneously in both countries, as conscious efforts are made to improve information about the other, about the nature of the threat, and the confidence we can summon that the threat is in fact changing and receding.

In similar fashion, the effort to solve the global environmental crisis will be complicated not only by blind assertions that more and more environmental manipulation and more and more resource extraction are essential for economic growth. It will also be complicated by the emergence of simplistic demands that development, or technology itself, must be stopped for the problem to be solved. This is a crisis of confidence which must be addressed.

This speech, if you'll permit me a personal moment, is the first time I've spoken in public on any subject in six weeks. My wife and I have been in Johns Hopkins Hospital, at the bedside of our son, who was hit by an automobile. I've been living in the world of medical science, pursuing the goal of restoring our son to health. Ten years ago, a child with his injuries would have had several surgical interventions which doctors now realize are unwise, given the greater likelihood of the body healing itself where some injuries are concerned.

Yet, two days after the accident, when doctors were unable to stabilize internal bleeding, my wife and I naively hoped that same natural healing process would take care of that problem and make any surgery unnecessary. If the doctor had relied not on science but on us, we would have unwisely urged against an operation. But doctors have acquired sufficient knowledge to realize that the body should be allowed to heal itself when it can do so. At the same time, they they know there are some instances where intervention is essential to save life.

Similarly, we must acquire sufficient knowledge of the earth's system to judge when it can heal itself, and when it is necessary for us to intervene. For example, when 40,000 children die of disease and starvation every 24 hours, we obviously must intervene. But it is past time to recognize that many of society's interventions in the environment have been and are unwise. Much ecological destruction is subsidized by governments. We need more knowledge, more experience, and the kind of sensitive judgments that modern doctors have learned to make.

The cross-cut between the imperatives of growth and the imperatives of environmental management, represents a supreme test for modern industrial civilization. The test is whether we can devise very dynamic new strategies which will accommodate economic growth within a stabilized environmental framework.

That is an extreme demand to place upon technology. There is no real assurance that such a balance can in fact be struck. Nevertheless the effort must be made. And because of the urgency, scope and even the improbability of complete success in such an endeavor, I am strongly tempted to use a military term for a metaphor. To deal with the global environment, we will need the environmental equivalent of the Strategic Defense Initiative, a Strategic Environment Initiative.

I have been an opponent of the military SDI. But even opponents of SDI recognize this effort has been remarkably successful in drawing together previously disconnected government programs, in stimulating the development of new technologies, and in forcing upon us a wave of intense new analysis of subjects previously thought to have been exhausted.

We need the same kind of focus and intensity, and similar levels of funding, to deal comprehensively with global warming, stratospheric ozone depletion, species loss, deforestation, ocean pollution, acid rain, air and water and groundwater pollution, and all of the problems degrading the world's environment. In every major sector of economic activity -- energy, agriculture, manufacturing, and transportation, for example -- a Strategic Environment Initiative must identify and then spread sets of increasingly effective new technologies: some that are already well in hand; some that need further work, though well understood in principle; and some that are revolutionary ideas whose very existance is now a matter of speculation.

Let me briefly illustrate:

Energy is the lifeblood of development. Unfortunately, today's most economical technologies for converting energy resources into usable forms of power (as in burning coal to make electricity) release a plethora of pollutants. An Energy SEI should focus on producing the energy of development without compromising the environment. Chief on the near-term list of alternatives are energy efficiency and conservation; on the mid-term list, solar power, possibly new-generation nuclear power, biomass (with no extraneous pollutants and a closed carbon cycle), as well as enhanced efficiency; and long-term, nuclear fusion, as well as enhanced versions of solar, biomass, and nuclear energy, and energy efficiency.

In agriculture, we have witnessed vast growth in Third World food production through the Green Revolution, but often that growth relied on heavily subsidized fertilizers, pesticides, irrigation, and overall mechanization, sometimes giving the advantage to rich farmers over poor ones. We need a second green revolution, to address the needs of the Third World's poor: a focus on increasing productivity from small farms on marginal land, with low-input agricultural methods. These technologies, whose components are not only technological, but financial and political, may be the key to satisfying the land hunger of the disadvantaged and the desperate who are slashing daily into the rainforest of Amazonia -- leaving behind the depleted soil of their first homesteads. It may also be the key in the battle to arrest the desertification of sub-Saharan Africa, where human need and climate stress are now operating in a deadly partnership.

Fortunately, the next wave of agricultural improvements is almost upon us -- from biotechnology. In my view, we should carefully push forward work on new crop strains with genetic encoding that allows "natural" resistance to pests, disease, and droughts; not to mention improved yield. Of course, biotechnology will not completely solve the problems that arise from inadequate distribution of food supplies -- they are most often due to a failure of politics, not crops.

In addition, new industrial processes, new materials, and increased use of recycled materials, will all become important to "sustainable" development.

Needed in the U.S. probably more than anywhere, is a Transportation SEI focusing in the near term on improving the mileage standards of our vehicles, and encouraging and enabling Americans to drive less. In the mid-term, come questions of alternative fuels, such as biomass-based liquid fuels or electricity. And in the mid- and long-terms come the inescapable need for re-examining the entire structure of our transportation sector, and its inherent demand on the personal vehicle for efficient transport.

Funds to promote these research objectives could be drawn from very modest US energy taxes, eventually perhaps even a CO2 tax, although that is not yet politically viable. The U.S. government should organize itself to finance the export of energy-efficient systems, and of renewable energy sources. That means preferential lending arrangements through the Export - Import Bank, and Overseas Private Investment Corporation.

Encouragement for the Third World should also come in the form of attractive international credit arrangements for energy efficient and environmentally sustainable processes. Funds for this lending stream would be generated by institutions such as the World Bank, which, in the course of debt swapping, might dedicate new funds to the purchase of environmentally sounder technologies.

Finally, the United States, other developers of new technology, and international lending institutions, should establish centers of training at locations around the world, to create a core of environmentally educated planners and technicians, in order to "make the ground fertile" for sowing environmentally attractive technologies and practices; an effort not unlike that which produced agricultural research centers throughout the world during the Green Revolution.

With this SEI, we must transform science and technology to make it more efficient, consume less of the earth's natural resources, and emphasize waste minimization, recycling, and the use of renewable resources in harmony with the natural world. We must start by quickly obtaining massive quantities of information about the global processes now underway -- through, for example, the Mission to Planet Earth program of NASA.

And we also must target first the most readily identifiable and correctable sources of environmental damage. Today, for example, I have introduced a new comprehensive legislative package to effectively halt chlorofluorcarbon, carbon tetrachloride, methyl chloroform, and halon emissions, and to promote development of technologies to replace those that now rely on CFCs. Earlier this year, I introduced the World Environment Policy Act of 1989, a far-ranging bill to address virtually every aspect of the global environmental crisis, including CFCs and CO2.

In order to accomplish our goal we also must transform global politics, shifting from short-term concerns to long-term concerns, from conflict to cooperation.

The evidence of the last six months leads me to believe we have the capacity for this change. Just as the equilibrium of an environmental system can suddenly change from one state to another, the equilibrium of one political system can suddenly change from one state to another. We politicians are frequently adept at symbolic action, a pretense of change without the substance of change. And for that reason, my optimism is tempered by awareness of the power in the forces of greed and fear. But I do believe we have the capacity for what is needed -- because the challenge can now be accurately described in terms of national security.

Some may believe that the idea of the environment as a national security issue is just rhetoric. Most of us in this room, however, accept it as a statement of fact. But, we also know that just as the world has been living with the possibility of man-made disaster in the form of nuclear war, so it now lives with the growing threat of man-made disaster in the form of catastrophic environmental failure.

In many ways, it is the same basic dilemma. In each case, our survival was threatened at a basic, primal level -- the fear of death from attack by an enemy, the fear of death from running out of food. To each threat, we responded with more and more efficiency. The increasing sophistication of our technology has enabled us to confront each threat to our survival with a more powerful response. And in each case, the effort to secure our survival has instead threatened our survival.

Moreover, even if we are successful this time in meeting the needs of our survival and preserving the world environment, it probably won't be the last time we'll face this basic problem. Genetic engineering may pose the same dilemma all over again. In the effort to protect ourselves against disease, we're creating a new and more powerful technology that ultimately will confront us with the same historic challenge to human nature and the same hubristic relationship of our species to the limits nature has designed for us as part of the world ecological system.

As a result, it is hard to escape the conclusion that we must also transform ourselves -- or at least the way we think about ourselves, our children, and our future. This last transformation is the most essential, and yet the most difficult. If there is one cause for the prevailing pessimism about our ability to meet this unprecedented challenge, it is the belief by many that we are incapable of the change in thinking required.

And yet, there are precedents which give cause for realistic hope. Human sacrifice and slavery were both once commonplace in human societies, yet both are now obsolete. Our thinking was transformed. These changes, like most changes in global climate patterns, took place over a long period of time. But now, just as climate changes are telescoped into short periods of time, we must create in a single generation changes in human thinking of a magnitude comparable to the change that brought about the abolition of slavery. Yet once again, we must remind ourselves that the pattern of change required is visible only from a distance.

In this case, we cannot rely on science to give us a new point of view for it is partly responsible for the problem. In ways not yet fully understood, the scientific revolution itself changed the way we saw ourselves in relation to the world. We detached ourselves from nature to examine the physical world. In a kind of Heisenberg Principle writ large, we altered -- without realizing it -- the nature of what we began to examine. The new pattern of thinking we must now create is one in which we once again see ourselves as a part of the ecological system in which we live. What we now lack is a sense of the proper location of our species in the ecosystem. We have lost our eco-librium.

How then can we gain sufficient distance from ourselves to see a pattern which contains ourselves in a larger context? My own religious faith teaches me that we are given dominion over the earth, but that we also are required to be good stewards of the earth. If we witness the destruction of half the living species God put on this earth during our lifetimes as a result of our actions, we will have failed in the responsibility of stewardship. Are those actions, because of their result, "evil"? The answer depends not upon the everyday nature of the actions, but upon our knowledge of their consequences. In an examination of Hitler's lieutenants, Hannah Arendt coined the memorable phrase "the banality of evil." The individual actions which collectively produce the world's environmental crisis are indeed banal when they are looked at one by one: the cutting of a tree, the air conditioning of a car.

"Evil," and "good" are terms not used frequently by politicians. But in my own view, this problem cannot be solved without reference to spiritual values found in every faith. For many scientists on the edge of new discoveries in cosmology and quantum physics, the reconciliation of science and religion sometimes now seems near at hand. It is a reconciliation not unlike the one we seek between man and nature.

But even without defining the problem in religious terms, it is possible to conclude that the solutions we seek will be found in a new faith in the future of life on earth after our own, a faith in the future which justifies sacrifices in the present, a new moral courage to choose higher values in the conduct of human affairs, and a new reverence for absolute principles that can serve as guiding stars by which to map the future course of our species and our place within creation.

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INQUIRY

Topic: THE OZONE SHIELD

*Sen. Albert Gore Jr., 40, D-Tenn., a candidate for the Democratic presidential nomination last year, has had a long-standing interest in the environment. He was interviewed by USA TODAY's **Paul McMasters** about environmental problems we face, including dangers of the shrinking ozone layer, which scientists are preparing to explore as they meet in Norway this week.*

Albert Gore Jr.

▶ Scientists to measure damage at North Pole, 1A

Nations must join hands against a global threat

USA TODAY: Two hundred scientists are in Norway this week preparing to assess damage to the Earth's ozone layer. Why should we care about that?

GORE: Because the ozone layer protects life on Earth from deadly ultraviolet radiation. The best-known consequence of increased UV radiation is a surge in the number of skin cancer cases and the number of cataracts. But far worse damage may occur to smaller life forms further down the food chain. The effects on plants and animal life of all kinds will be very difficult to predict. But we know that those effects range from very bad to catastrophic.

USA TODAY: What do you think the scientists will find?

GORE: It's premature to speculate on what they may find, because this problem has repeatedly surprised scientists who, for example, did not expect the ozone hole discovered only a few years ago above Antarctica. What was predicted, however, was the destruction of stratospheric ozone by the accumulation of chlorofluorocarbons — CFCs. This expedition will undoubtedly find further evidence that is occurring.

USA TODAY: Isn't the problem confined to the polar areas?

GORE: There is a misconception that the hole over Antarctica and other holes, which may be found in the Arctic, represent the only manifestation of the problem. There has been a 4% reduction in the thickness of the ozone layer over the entire world. The findings in Norway will be important in improving our understanding of how fast this is occurring, and how we can stop it.

USA TODAY: The Montreal Protocol, signed by 24 nations, should reduce CFCs by 35% by 1999. Won't that delay any real problems?

GORE: No, not at all. The Montreal Protocol was a useful first step, and extremely important because it demonstrated the ability of nations to work together quickly when confronted with a challenge of this kind. But it also represented a compromise with commercial interests and a compromise with the nations that were reluctant to move at all. Consequently, it is grossly inadequate.

USA TODAY: How much do we need to reduce CFCs, then?

GORE: In order to stabilize the rate of damage, we would have to reduce the levels of CFCs by 85%. So if the Montreal Protocol is our only response, then we will not only see continued destruction of the ozone layer, we will see a continued acceleration in the rate at which it is destroyed. Moreover, the same chemicals responsible for virtually all of the ozone destruction are responsible for 15% to 20% of the "greenhouse effect" — a possibly calamitous global warming trend. It's ridiculous to allow the continued production of such harmful substances — 90% to 95% of them should be phased out within five years.

USA TODAY: Is that even remotely possible?

GORE: That sounds like an unrealistic and ambitious goal, but it is only prudent. Indeed, it is ridiculous not to set and meet such a goal.

USA TODAY: But people depend on CFCs as a refrigerant, spray-can propellant, insulation in fast-food containers. Is it realistic to think we can quit CFCs cold turkey?

GORE: If they are required to do so, they will quickly find substitutes. We should allow a 1% to 2% exemption for essential uses for which no substitute can be found. But let's take the case of aerosol sprays. We were told when the U.S. ban was considered 13 years ago that we might have to do without aerosol cans. But in fact, when the ban took place, there was absolutely no effect in the marketplace. We had a readily available substitute that was used without people even being aware of the change. There are similar substitutes waiting for automobile air conditioning, disposable packaging and virtually every other use.

USA TODAY: Are substitutes for all uses available?

GORE: There are some uses where substitutes will take a little more time to develop. Nevertheless, even there, the sudden appearance of a highly profitable, brand-new mass market will in all likelihood pull these substitutes into the marketplace quickly. But the point is, the alternative is unthinkable. How can we possibly weigh a relatively small commercial interest against the health and environmental conditions of all future generations? There's a problem of scale here. We can't use traditional cost-benefit analysis when the environment of the entire world is threatened.

USA TODAY: Do we have an international and national political climate now that will allow us to take significant action against the environmental problems we face?

GORE: No, not yet, but the political environment is changing almost as fast as these environmental problems are emerging. People in every country are increasingly concerned. Leaders like Britain's Margaret Thatcher, who dragged her heels a year ago, are now taking forward-looking positions and helping to lead the charge. However, the awareness of how serious our global ecological crisis has become has not yet reached the level where the necessary political response is at hand. But we are getting close.

USA TODAY: How close?

GORE: I expect to see a dramatic change in the interaction between nations on these global environmental problems, the worst of which is the greenhouse effect, which serves as a defining metaphor to represent the impact of human civilization on the world environment with the consequent loss of species at a rate that has not occurred on Earth for the past 65 million years — the loss of forest land, the loss of the stratospheric ozone layer, the loss of topsoil, the accumulation of pollutants in the oceans and the ground water.

USA TODAY: Is it more likely that the real solution to these problems — given the enormous cost and complexity — is just to adapt as the environment changes?

GORE: The advice to adapt rather than prevent these changes is unwise counsel. The changes are occurring so rapidly that adaptation will not be possible without major disruptions in our civilization. The advice to adapt is an obstacle to the correct political response, which is prevention.

USA TODAY: That's not the only obstacle, is it?

GORE: No, there are others. There is a general tendency to dismiss problems so large and unprecedented because they are outside the scope of our historical experience, and what we call common sense. There is also a tendency to shy away from solutions that are unimaginably difficult and that require global cooperation on an unprecedented scale. But all of these obstacles must be overcome in the lifetimes of those now living. Or else our grandchildren will ask themselves why we didn't react. The fact is, we must.

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"What Is Wrong With Us?"

A Senator's impassioned call for action

If the steps needed to save the environment are well known and feasible, then why are they not taken? In a speech at the TIME *conference, Senator Albert Gore of Tennessee, one of the most ardent environmentalists in Congress, explored this crucial question. Excerpts from his remarks:*

When I announced I was running for President, I said the greenhouse effect, the depletion of the ozone layer and the global ecological crisis will, by the end of this election year, be recognized as the most serious issue facing this country and the world. Three days later, a George Will column ridiculed the naiveté of a politician who could imagine that issues of this kind would be politically salable.

I guess he was partly right and partly wrong. I was right in that the issue has, during this year, attained enormous importance and new recognition. But he was right, since it didn't do me any good politically. There are still barriers to political action. Let me discuss five of them.

▸ Number one, there are areas of uncertainty about the greenhouse effect and the dire nature of the ecological crisis we face, which are seized upon as excuses for inaction. This is a psychological problem common to all humanity. If strong responses are needed and yet there is some residual uncertainty about whether you are going to have to make those responses, the natural psychological tendency is to magnify the uncertainty and say, "Well, maybe we won't really have to face up to it."

But the fact that we face an ecological crisis without any precedent in historic times is no longer a matter of any dispute worthy of recognition. And those who, for the purpose of maintaining balance in debate, take the contrarian view that there is significant uncertainty about whether it's real are hurting our ability to respond.

"Did God choose an appropriate technology when he gave human beings dominion over the earth? The jury is still out."

▸ The second barrier to political action is an unwillingness to believe that something so far outside the bounds of historical experience can, in fact, be occurring. To put it another way, this set of problems sounds like the plot of a bad science-fiction movie. People automatically assume it can't be real.

▸ The third political barrier is the assumption that it will be easier and more sensible to adapt to whatever climate change occurs than it will be to prevent the crisis. But the change could come so swiftly that adaptation will be all but impossible.

▸ The fourth barrier is the lack of widespread awareness among the peoples of the world about the nature of the problem. Most political leaders, let alone their public, are unaware of what is happening and how severe it is. That must be changed.

▸ The fifth barrier to political action is the knowledge that many of the ultimate solutions are almost unimaginably difficult. And since they are harder than anything we have done before, and the efforts may all come to naught anyway, why mess with them? Why not conserve our energy and just not even try? That is a formidable barrier, not least because the solutions require international cooperation on a scale that is totally unprecedented in history.

Those five barriers must be overcome before the political system reacts. The role of leadership is critical in spreading awareness, in framing solutions, in offering a vision of the future we want to create, as well as a vision of the nightmare we wish to avoid.

There is an old science experiment in which a frog is put into a pan of water, and the water is slowly heated to the boiling point. The frog sits there and boils because its nervous system will not react to the gradual increase. But if you boil the water first and then put the frog in, it immediately jumps out.

We are at an environmental boiling point right now. Is the destruction of one football-field's worth of forest every second enough to make the frog react and jump out of the pan? What will it take? If, as in a science-fiction movie, we had a giant invader from space clomping across the rain forests of the world with football field-size feet—going boom, boom, boom every second—would we react? That's essentially what is going on right now.

We saw the two whales trapped in the Arctic ice, struggling for air, and the world responded. The U.S. and the Soviet Union cooperated. Yet we see 40,000 babies starving every day, and we don't react. What is wrong with us?

There used to be a debate in the '70s about appropriate technology. Now the question is: Did God choose an appropriate technology when he gave human beings dominion over the earth? The jury is still out. And the answer has to come in our lifetime from the political system.

There are precedents. We made human sacrifice, once commonplace, obsolete. We made slavery obsolete. These things, just like changes in weather patterns, took a long period of time. But now, just as climate changes are telescoped into a very short period of time, changes in human thinking of a magnitude comparable to the changes that brought about the abolition of slavery must take place in one generation.

We know how to solve the problem. It will be unimaginably difficult. The cooperation required will be unprecedented. But we know what to do. What is required is a change in thinking and a change in the equilibrium of the world's political system.

Right now the political equilibrium is characterized by short-term policies at the expense of long-term policies. It is characterized by actions to confer national advantage at the expense of actions designed to promote global advantage. It is characterized by preparations for war, ignorance and starvation.

Our challenge as political leaders is to come up with an agenda of solutions, which we are doing. But the larger challenge for all of us is to shift the world's political system into a new state of equilibrium, characterized by more cooperation, global agendas and a focus on the future. As General Omar Bradley said at the end of World War II, "It is time we steered by the stars and not by the lights of each passing ship." ■

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POSTCARD ANTARCTICA

UNBEARABLE WHITENESS

I'M TRYING TO remember what I thought about Antarctica before I came here. For the most part, I didn't think about it at all. It is just plain remote. From the other side of the world, in Christchurch, New Zealand, it is another eight hours due south by plane to the main U.S. base, McMurdo, and then another three hours from there to the South Pole.

I came to the coldest place on Earth to hunt for information about global warming, but I was unprepared for the continent itself. For example, I didn't know that the land area is half again as large as the entire United States. Or that 90 percent of all the ice in the world is here—which means, among other things, that there is really no comparison between this place and the Arctic. Antarctica is larger, more isolated, more important in the global ecosystem—and much colder.

You don't expect a continent at the "bottom" of the world to have an altitude three times higher than any other continent. When I stepped out of the ski plane at the Pole, my awareness was divided between the 56-degree-below-zero weather and the dizziness of being at almost 10,000 feet. The altitude of the enormous polar plateau is due primarily to ice that is almost two miles thick. Although its ice and snow contain 70 percent of all the fresh water on Earth, Antarctica gets so little precipitation that it is classified as the world's largest desert. And while the continent goes dark for six months in winter, it still receives more sunlight during its six-month-long summer day than the equatorial regions receive in an entire year. Yet all that light creates virtually no surface heat, because most of it is reflected right back up into space. For anyone caught in that crossfire of whiteness, sunglasses are a medical necessity.

The ice shelf expands in winter to seven times its summer maximum. The small population of human beings sent here by 22 nations expands in summer and contracts in winter by proportions almost precisely inverse to those of the ice.

WHILE MOST of Antarctica is the cleanest, most pristine area on Earth, the waters immediately adjacent to the American base are among the most polluted in the world. PCBs and "we don't know what else," dumped years ago, have killed every vestige of life in a small area of McMurdo Sound. The nuclear power plant that leaked in 1962 was dismantled and returned to the United States. But even today the base dumps "diluted" raw sewage directly into the sound and burns its solid waste in an open pit.

In the last few years, several other developments have brought new attention to Antarctica. In 1986 an emergency expedition confirmed the existence of a large and growing polar hole in the stratospheric ozone layer (which protects humans from deadly ultraviolet-B radiation). The same team found incontrovertible evidence that man-made chemicals called chlorofluorocarbons (CFCs) were responsible.

A new international agreement was signed this year to reduce CFC production a little, though not enough. Meanwhile, the world's fossil fuels are being burned at such a rapid rate that the resulting carbon dioxide, along with other "greenhouse gases," may have already triggered the long-predicted global warming. At least some scientists said this summer that they are finally convinced.

The air is clearer and crisper in Antarctica than anywhere I've ever been, and visibility is remarkable over great distances. But that can suddenly change, as I learned firsthand, during something known as a "whiteout." The winds of a sudden storm saturate the air so thoroughly with snow that first the horizon, then closer landmarks, and then even the hood of your vehicle can disappear in a shroud of whiteness. Travelers lose their orientation and perspective. Some tell stories of seeing a building in the distance only to find that it was a pack of cigarettes a few feet away. Having just lived through a general election campaign in which Willie Horton was a more prominent political landmark than the budget or trade deficit, I had the feeling I had gone from one whiteout to another.

I CAME HERE because Antarctica is now the frontier of the global ecological crisis. High in the Transantarctic Mountains, a badly sunburned scientist talked about the ice cores he and his team were pulling from a deep hole drilled into the glacier on which we stood. He interpreted the annual layers of ice and snow the way woodsmen read tree rings. "Here is where the U.S. Congress passed the Clean Air Act," he said, pointing to the beginning of the 1970s. Moving down the ice core, back to the early 1960s, he added, "And here is where the world stopped atmospheric nuclear testing." These and other ice cores contain highly accurate information about the makeup of the Earth's atmosphere year by year for tens of thousands of years. From such cores, we know, for example, that there were dramatically lower levels of carbon dioxide in the atmosphere at the peak of the last Ice Age, 20,000 years ago, when the island of Manhattan was under one kilometer of ice. By contrast, the ice and snow laid down in the 1980s show levels of carbon dioxide, methane, CFCs, nitrous oxide, and other gases responsible for the greenhouse effect higher than they have been in at least 160,000 years (as far back as the ice cores measure). CFCs are receiving particular attention because they cause not only 20 percent of the greenhouse effect but virtually all of the destruction of the ozone layer.

Something else is different about the ice layers from the 1980s—they *look* different to the naked eye because of thick, alternating layers of "hoar" ice, apparently caused by partial melting and recrystallization into larger granules. The scientists are as yet cautiously withholding judgment on whether this is the clear signal of Antarctic warming that many have anticipated.

When I say Antarctica is the frontier of the ecological crisis, I don't mean only that pollution can now be found at the remotest point on Earth. Antarctica is also the place where both ozone destruction and global warming have their first and most dramatic impacts. It is also increasingly apparent that Antarctica plays a far more significant role than any other part of the Earth in the global climate system. For one thing, the cold waters surrounding the continent absorb more carbon dioxide from the atmosphere than all the rain forests, and create the nutrient-rich "bottom water" for most of the world ocean of which Antarctica is the epicenter. Also, aside from the sun and the rotation of the Earth, Antarctica is the single most powerful engine driving the world's weather, redistributing its massive coldness through the winds of the air and the currents of the sea. As greenhouse gases trap more heat in the Earth's atmosphere and temperatures climb, they are expected to climb fastest of all here in Antarctica, because any melting at the edge of the ice shelf is accompanied by a dramatic change in the albedo—reflectivity—of the surface exposed to sunlight. The increased absorption of the sun's rays by the ocean then magnifies the local warming trend, melting more ice at the margin and absorbing yet more radiation from the sun.

THERE ARE three potential catastrophes that scientists fear could eventually be caused by the warming of Antarctica. First, a dramatic rise in sea level. This would come not from the melting of sea ice, which is already floating in the ocean, but from a rapid breakup of the massive West Antarctic ice shelf, which scientists believe could then plop into the ocean, raising the sea level 15 to 20 feet, wiping out low-lying coastal cities and nations like Bangladesh. But this is further off than most greenhouse impacts, perhaps 200 years.

Second, something that some scientists worry could occur much sooner is a change in the ability of the Antarctic seas to absorb carbon dioxide as they get warmer. Partly because it is so cold, the southern ocean now absorbs between one-third and one-half of all carbon dioxide emissions from industrial nations. Since carbon dioxide is by far the most important greenhouse gas, we must concern ourselves not only with the rate at which our civilization produces it but also the rate at which the Earth absorbs it.

The Earth has two lungs—the forests and the southern ocean. Unfortunately, we are destroying our forests at the rate of one football field every second, an area the size of Tennessee every year. Since the oceans of the world contain 50 times as much carbon dioxide as the atmosphere, even small changes in the temperature-sensitive mechanisms by which carbon dioxide is transferred back and forth between the oceans and the air can have profound implications.

Third, scientists fear that if their predictions are correct, and temperatures at the poles increase far more rapidly than at the equator, then the very pattern of the world weather system might change. This is because the difference between temperatures at the equator and at the poles has been relatively constant for a long time. As a result, the redistribution of heat from the equator to the poles and cold from the poles to the equator has been accomplished through an essentially constant pattern of wind and ocean currents. If temperatures rise disproportionately in Antarctica, the equilibrium could change, creating new patterns that would redistribute less cold and more heat. Something like this once happened on a small scale in Greenland. The so-called "little ice age" beginning 500 years ago abruptly covered the southern and western agricultural areas that gave Greenland its name with the ice and snow that now make people wonder where the name came from.

Similar though larger and anthropogenic global weather changes now thought to be under way are expected to cause widespread droughts and heat waves within our children's lifetimes. Indeed, some argue they have already begun.

In spite of these enormous stakes and in spite of the central role played by Antarctica, an international scientific conference in Tasmania this fall concluded, "There is no established strategy either for early detection of climate change in Antarctica or understanding and prediction of the probable effect of climate warming on atmospheric and oceanic circulation, ice-sheet volume, and sea level."

Even at that, the scientists are further along than the politicians. Why are we waiting to act?

Perhaps partly because of the unprecedented nature of the crisis. It is simply beyond our experience and outside of what we call common sense. So we put it in the place in our minds where Antarctica exists and tag it with the same mental labels—remote, alien, hopelessly distorted by the maps of the world we inhabit, too hard to get to and too unforgiving for us to stay very long.

The real question is whether the world's political system can find a new equilibrium before the world's climate system loses its current one. Even now, the winds of change are approaching hurricane force. It took a million years for the population of the world to reach two billion. Now, in the course of a single human lifetime—mine—it is rocketing toward ten billion (and is already halfway there). Startling graphs showing the loss of forest land, topsoil, stratospheric ozone, and species all follow the same pattern of sudden, unprecedented acceleration in the latter half of the 20th century. And yet, so far, the pattern of our politics remains remarkably unchanged.

When it does come, the change will involve a new set of global goals, and a new way of thinking about ourselves, our children, and our whole world—even Antarctica.

AL GORE

Al Gore is U.S. senator from Tennessee.

Senator Wirth. All right, thank you very much, Senator Gore, and we really appreciate the terrific work that you have done from the time that nobody had any idea what this issue was all about to today, and continuing to be out front on what is—as all of us, I think have suggested and everybody will come to understand, the greatest challenge and we are going to face for all of our lifetimes, I think.

We have this morning a very distinguished first panel of witnesses and a very distinguished second panel. Let me start with the first panel, if I might. Dr. Stephen Schneider is Senior Scientist for Atmospheric Research in Boulder. NCAR is a national science foundation supported consortium of universities and Dr. Schneider is one of the pre-eminent global atmospheric scientists in the world. Dr. Peter Gleick, the Director of Global Environmental Programs at the Pacific Institute for studies in development environment and security in Berkeley. He is also no stranger to the environmental climate world and, Peter, we're delighted to have you with us today. And finally, Dr. John Dracup from the Department of Civil Engineering at UCLA, right here in our own backyard to give us a picture of these specific impacts with special reference to water in California.

Gentlemen, we thank you very much for being with us and why do we not just move right down from you, Dr. Schneider, to Dr. Gleick, to Dr. Dracup, if we might do that. And we will include your statements in full in the record, and we look forward to receiving your testimony. Thank you all very much for coming. We greatly appreciate it. Dr. Schneider.

STATEMENT OF DR. STEPHEN H. SCHNEIDER, SENIOR SCIENTIST, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH, BOULDER, CO

Dr. Schneider. Thank you, Senator Wirth. While I get the slide projector in order and wait for the front panel lights to go out, because I can do in a few minutes, a quicker job of what I was asked to do which is survey what we know very well, what we know to some extent and what we don't know about the global warming issue, so we have some perspective. But, while that is happening, if I can indulge myself momentarily in a personal note, seeing Senator Cranston on the panel reminds me of the time when I first saw him on a panel on the subject of climate change which was in 1977 in San Francisco, at a regional hearing. You may remember, Senator, you and Senator Stevenson were there. That was the first time I had ever had the privilege of testifying before the Senate, and also the producer that was covering that for KRON-TV is now my wife. So, I owe you that.

Well, let me begin with a picture that's becoming very familiar to people who study and who are interested in the global warming question. In fact, we owe this picture considerable debt to the State of California because Professor Roger Revell who has set up, part for the U.S. the International Geophysical Year began by convincing Charles David Keeling to put a measuring system up at Mount Aloha Observatory in Hawaii and it is the continuous record. This is a thirty-year long version of the record of the amount of carbon dioxide concentration in the atmosphere from the time measurements began in 1958 through 1988.

Now, what we can see is there is about three hundred and fifteen parts per million of carbon dioxide on the atmosphere. Now, that doesn't sound like very much. This is back in 1958 by the way, and there's about three hundred and fifty parts per million now, about a ten percent increase. So, we're quite certain that that increase is caused by human activity, in particular the burning of fossil fuels and to some extent, deforestation. But what's interesting is many people in their own wisdom will say, "Wait a minute, that's not very much. I mean, three hundred and fifteen parts per million, that's only if you do the arithmetic. That's only about three hundredths of one percent. How can something that's only three hundredths of one percent be so important". And I remind people just be metaphor that if you took the very small fraction of your blood that's hemoglobin out, it would make almost no difference, but it would be very difficult to get oxygen from your lungs to your cells.

So, small percentages of things are no reason to avoid thinking seriously about an issue. And in this case, what we've done is, we've literally had millions of satellite measurements and thousands of balloon and aircraft measurements, and hundreds of laboratory measurements which tell us that this gas has the property of letting sunlight through more easily than another kind of radiation, so-called infra-red radiation. Now, the reason it's so important is that this ten percent increase since 1958, which is largely due, we believe to burning fossil fuels, as I said, about twenty percent of that from deforestation, is not just simply a small fluctuation.

We have records that literally go back through two Ice Age cycles, through 150,000 years. And we know that during the Ice Ages which were about five degrees Celsius or nine degrees fahrenheit colder than the present so-called inter-glacials. There was about twenty-five, thirty percent less CO_2 then. Then for about ten thousand years, there was something like two hundred and eighty parts per million of this gas and only in the very, very recent history, since the Industrial Revolution, has it taken this jump up to three fifty. It's already an unprecedented territory in modern geologic times.

So, that's a background and a backdrop against which there's essentially no controversy in the scientific community. About a twenty-five percent increase in CO_2 since the Industrial Revolution is now well-documented. Well, the reason it's important, of course, is that CO_2 is one of the so-called greenhouse gases and it is always necessary to explain what the greenhouse effect is, which I think is best done in this slide.

And Time Magazine put on the cover a long time ago, with a greenhouse around the earth. And, of course, that is not how it works on the earth, but it does remind us how a greenhouse works. A greenhouse lets sunlight in and then it traps heat inside. It does that by physically blocking the exchange of the warm air with the cold air. The greenhouse on earth is brought about by a different mechanism. It's brought about by the mechanism of the gases around the earth's atmosphere letting the sunlight in more easily and then blocking out the other kind of heat, the infra-red radiative heat. This picture, of course, shows that for the earth.

And once again, we will read in the newspapers that there's controversy about the so-called greenhouse effect. But, in reality, the greenhouse effect as a scientific proposition has no controversy in the community. It's very well understood, as I had said from literally millions of measurements, that the properties of the atmosphere are such that about fifty percent of the sun's energy reaches the earth's surface and is absorbed, heats the planet. Some of that then is used to evaporate water and other kinds of direct heat transfer. Then a much larger amount of energy is radiated up from the earth's surface, but it's trapped by clouds and gases in the atmosphere, water vapor, CO_2, methane and others. And much of that is re-radiated back down.

So, this heat trapping capacity of these gases is the part that's established beyond doubt. It doesn't mean there isn't controversy surrounding the term greenhouse effect. The popular use of the greenhouse effect refers not simply to the heat trapping properties which are well understood beyond doubt, but to how much that extra heating of the atmosphere when you add gases, how much that extra heating in this term here, will increase temperature, will it be one degree or five or then, will it be fifty years or a hundred or a hundred and fifty? That's the area where there's some debate, not that there's heat trapping capacity or that the gases are increasing.

Well, despite that, this popular discussion of this issue, this was an article in the New York Times in late January of 1989. And the headline said, "U.S. Data Since 1895 Fails to Show Warming Trend". And, in fact, the people who produced that report now say that that probably wasn't quite right. There was a warming trend after all, a couple of tenths of a degree, but it was less than the global one.

And I remember after that article—which by the way, was an excellent article, if you continued it on page A-14, because it pointed out that the United States represents only a couple of percent of the world's area and it's essentially irrelevant what happens in a small fraction; that there's lots of fluctuations. There are parts of the world warming up by several degrees. Parts are cooling down by several degrees. And at the level of heating that we have so far, you cannot expect what happens in your own backyard or in a few years, to be valid experience. And, in case anyone was confused, this was in January—late January of 1989.

The next one was one week later in the same newspaper, the New York Times and the same author, Phil Shaberkoff, wrote another good article whose headline reads, "Global Warmth in 1988 is Found to Set a Record". Now, many people get confused by that kind of headline conflict. And, again, the article was good and it pointed out that on a global basis, 1988 was the warmest year on record, followed by 1987 and that five of those years had happened in this decade, as we've heard earlier in the opening statements.

Well, the point is, we've had a coincidence of twenty-five percent increase in CO_2, a hundred percent increase in methane, release of fluorocarbons and other gases with a warming on the planet. Is that cause and effect? And there is legitimate controversy over that issue, because—there's pictures of the actual temperatures of the earth as put together by two groups. And, there's legitimate controversy because unfortunately, when this network of thermometers was set up, it was not designed to measure one degree or half degree changes in the planetary temperature as a harbinger or a canary, if you will, for the fact that the world was changing. It was simply designed to monitor weather events.

So, no care was taken to see to it that the thermometers were always in the same place. They were moved out to cities. Substantial artificial climate changes would be inferred if you don't correct for that. Cities grew around other thermometers and warmed them. And as a result, we've had to try to correct for these. And these graphs, which show about a six- to seven-tenths of a degree C warming in the case of a British group and about eight-tenths of a degree for Goddard Super Space Studies Group headed by James Hanson, they're both in agreement of this rough one degree fahrenheit warming trend.

Now, corrections have been applied for urban effects and perhaps they need to come down a few tenths, but then there are whole areas of the globe that are not covered. Maybe it needs to go back up. We just don't know, but we do know it is warming on the order of one degree fahrenheit, plus or minus several tenths of a degree has taken place during the century. And this is consistent with the increase in greenhouse gases. It is not absolute proof. On the other hand, how would you know, if you took a pair of dice and you loaded them so that they would not come up snake eyes very often and you rolled them, you still got two snake eyes in a row, would that tell you that you certainly had not loaded the dice. Certainly not. You would have to continue rolling them thirty, forty times to find out the true odds.

So, the message essentially is that individual events, such as a very hot year do not prove a greenhouse effect any more than one cold wet year disproves it. We have to continue to roll, as it were, and wait for nature to tell us that we've loaded these dice. So, what we've seen so far is consistent with that theory. The problem is, if we wait the ten or twenty more years it will take to establish beyond any doubt that the connection between the increased greenhouse gases and the climate change is established then we do that at the price of performing that experiment on a laboratory called earth with us and other living things along for the ride. Now, whether to take that chance is not a scientific issue.

And I am afraid that it is true, as we heard in the earlier statements, that it will be politically difficult to convince people of that because people live within their local experience. What we are talking about is an experience that is hard to direct from something that happens locally or even in the last ten or twenty years. You need global span and decades to do it. So, we have to learn how to shape our thinking toward global issues and not just simply dealing with what's immediately around us.

On the other hand, as the climate continues to warm, it will become increasingly obvious everywhere. And the way we will feel that is through increasing probability of extreme events such as heat waves and droughts and so forth. And I want to focus on those next. I had mentioned that the carbon dioxide had increased twenty-five percent since the Industrial Revolution and largely said that that was due to fossil fuels, but there was a component from deforestation and this picture shows land clearing in Malaysia in this case, and the point is that although we in the developed world are the principal producers of the fossil fuel pollution at present, the developing countries are involved in CO_2 through deforestation.

Now, our use of fossil fuels was not done for the purpose of polluting the environment any more than their deforestation is. It is a side effect. And what we have to recognize is that any economic activity that we have which provides benefit, employment, growth and so forth, certainly what while we may have social applause for such activities, certainly we need to, in calculating how much of that activity take place, have to account for the costs, and these are real costs, not just aesthetic costs, but dollar costs—the environment has dollar value. We have to account for those costs at the same time.

And any system which is purported to be a free market system that has not price for pollution is not a free market. It is a market that is preserving the status quo, not providing the right economic signal for us to try to use markets to evaluate how best to distribute resources. So, we need to find ways—and this will, of course, be the legislative challenge—to incorporate the value of the environment into the price of doing business so that the market can really work.

Well, I have shown CO_2 and there are other gases. This is a rice paddy in Bali in Indonesia, and rice agriculture is a mainstay of many developing countries. And if you flood a field which is rich in organic matter with water, then the bacteria that are in that organic matter and not exposed to the air and the kinds of bacteria that like to do that, produce lots of methane. And methane is natural gas, is a product that lives about ten years in the atmosphere and has twenty to thirty times more effect per molecule as a greenhouse trapping gas, greenhouse gas than CO_2. And methane is about double since the Industrial Revolution.

And we certainly recognize that rice agriculture is part of this world economy. So, this isn't a problem only for us. This is a problem that we have to recognize needs international negotiations to deal with. Well, the way we then try to figure out what's going to happen is, we make scenarios of how many people will be on the plant, what kind of standard of living they'll have and what sort of technology they will use. If they are using coal, they will produce twice as much CO_2 as if they are using natural gas. If they are using solar or nuclear or some renewable, they will not be producing CO_2 except that which it takes to build and decommission the power plants. There may be other issues involved there with cost and safety, but nonetheless, we have some control.

But in order to know the future, we have to forecast all those factors and nobody can do that perfectly. So, what we do in the scientific side, is we make scenarios. And this is typical of the kinds of scenarios we make. So, we project what people will do, how many there will be and so forth. We also project what that means in terms of how much buildup of greenhouse gases. Then we try to use some kind of computer model to estimate how much the climate change will be.

Well, these computer models do present results for the present earth. It looks something like earth, but they are not perfect and remember the picture earlier showed clouds as an important component of the greenhouse effect. Well, we have to forecast how clouds change, if clouds get bigger or they get wider and they cool the planet down, if they get taller, their tops get cold and they heat the planet up. So, we have a so-called feed-back problem. And that is another reason why, when you hear about controversy and the greenhouse effect, it is not over the heat trapping issue. It is over the extent to which internal changes in the system will either amplify or reduce the estimates that we make.

So, we produce charts such as this which bracket very fast rate of change where we could have as much as five degrees Celsius warming by the middle of the next century and I have no hesitation in labeling that one catastrophic. That is as much change as we saw from the end of the last Ice Age to the present inter-glacial which took nature ten thousand years and we would be doing it in less than a century, down to about one degree warming, that is the low end of the spectrum. And then in the middle, it shows warming on the order of two to four degrees Celsius now, before the end of the century, maybe even more.

That is beyond the range of experience by human civilization. That is the middle guess. Now, the important question is what is the probability of these and I really cannot tell you that we have an objective way to evaluate that. We have to use our intuition. We have to use surrogate methods to validate. Maybe there is only a five or ten percent chance that the climate would warm only as little as one degree and maybe only a five percent or a ten percent chance that it would warm as much as five in the middle of the next century and a much better odds that it would warm up something in the two to four degree range by the middle part of the next century. But, what we need to recognize is, when someone comes along and says, "Well, there is uncertainty and you are not sure and maybe it is going to come out on the low end and why should we invest substantial sums of money doing things differently for down there". And I had this very argument with Government officials. My answer always has been, "But if you want to cite uncertainty as a reason not to act, you have to be fair and you have to cite that that same uncertainty that could make it a lower effect than we now anticipate is just as likely to make it a higher effect". And what we are literally doing is flipping a coin. And one face of that coin says dramatic unprecedented climate change in the future because that is the kind of odds that we are talking about.

So, the scientific community is not presenting the message that we know for certain will happen, but we know a fair amount about the rates and magnitudes of change. And we certainly can make first decimal place odds, sort of coin-flipping or better odds statements. Let me conclude by saying, how do we validate these kinds of models? Well, the best climate experiment that we can have to try to validate them really is not a new or a shocking idea, simply the seasonal cycle. The present temperature difference in winter and summer in the northern hemisphere is about 15 Celsius, something like 25 degrees fahrenheit. That is much larger than we expect from the greenhouse gases in the next century.

And the question is, how well do these computer models do in reproducing the temperature differences between winter and summer. And the answer is, they do very well, do better than eighty percent. If we were making a fundamental mistake, a factor of ten error which is going to lead to some mechanism that will save us, it would be almost inconceivable that we could get observed and computed temperature differences between winter and summer to the extent that the models do.

While this does not confirm the details of where it is wetter and drier for example, it certainly confirms that the basic heat trapping idea which is well understood, and also capture by models is extremely likely to be true. Finally, what does it mean? Well, in the west, I think the two areas where we will need to concentrate on—and our next witnesses will do this in detail—are water, shown in this particular photograph in Lake Dillon, I am sure Senator Wirth recognizes, in a quote "normal year" and this is an important part of the Rocky Mountain water shed. And here was a drought year. We could see how very low these levels were.

Now, nature will continue to have wet and dry years. The individual fluctuating years are not going to be quote "caused by the greenhouse effect". But if you turn up the heat, it increases the evaporation and that also increases the demand for water as we will hear in a few minutes, which then adds to the stress. So, when you hear people make the statement that they expect the frequency of drought events to increase, it is not based on our certain knowledge that it is going to be less rainfall. It is that we expect the fluctuations to continue but when the negative ones occur, they will be intensified by the heating.

That is the basis of that. And again, while I cannot assure you that that will happen, that is a much better than even betting odds kind of statement. And then another—this is a picture of the front range of the Rocky Mountains right over where I live and also Senator Wirth does. And that is in Boulder, Colorado. And this is something very rare. We are about 20,000 feet in the air and this is a completely hazy day. That is not seen too often. We know that there are air pollution problems in Denver, but it does not mix up with the whole front range and go up to 20,000 feet. And as the plane climbed to 22,000 feet, you could see a very sharp difference with the blue sky above and the dark polluted look down below. And this picture was taken two years ago. I was flying to Salt Lake City in September.

And what that was, is that was the smoke from the forest fires in California. So, the point that we also worry about is the probability of wild fire depends upon extended hot periods. And, indeed, nature will continue by its own internal devices to roll us, if you will, hot periods. But if we turn the heat up a few degrees, that can have significant impact on the frequency of forest fires or the intensity of wild fires and at the same time, force species that are now adapted to one location to die and while new ones are growing, we have all these mature trees that will be dying that then become tinder for those fires.

So, even if in the long run new species that would succeed would be economically and aesthetically and ecologically valuable during that transition, we run substantial risk of increasing fires. Okay, let me conclude now with the last two pictures. This is a picture that I refer to as outdoor dentistry. I took it a number of years ago in Kathmandu, Nepal. And as you can see, the condition of the patient is not too happy being taken care of outside. And the reason that such scenes are repeated frequently around the world has to do with the level of affluence in many of these countries. The high population growth rates coupled with low access to resources is driving up demand for countries like China and India and other such places to get access to the kinds of technologies that we developed, but this raises a fundamental problem, which is, the total amount of pollution is equal to the product of the population size times the per capita standard, times the kind of technology. And how will we have the moral authority to tell the Chinese not to use all their soft coal which is a highly polluting fuel when we did the same sort of thing ourselves, unless—and this is the challenge, of course, to our leaders—unless we can show that we are willing to be more efficient ourselves and help provide resources to them so that they can find alternative, less polluting ways to develop.

Because whatever power plant the Chinese build now, they will have it for fifty years. If they build a thirty percent efficient power plant, we will have fifty years of having seventy percent of that energy wasted. If they build a fifty percent efficient power plant, then we will have thirty or fifty years with much less energy wasted. So, what we need to recognize when we talk about global warming is there are a hierarchy of things we have to do from cleaning up our own act to large sets of negotiations with other countries and finding that balance between fairness, giving them the chance to develop effectiveness, seeing to it that we have investments will be the challenge. Thank you very much.

[The prepared statement of Dr. Schneider follows:]

PREDICTING FUTURE CLIMATE: CAN IT BE DONE RELIABLY?

Testimony of

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P.O. Box 3000
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before

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PREDICTING FUTURE CLIMATE:
CAN IT BE DONE RELIABLY?

The Earth's climate changes. It is vastly different now from what it was 100 million years ago, when dinosaurs dominated the planet and tropical plants thrived at high latitudes; it is different from what it was even 18,000 years ago, when ice sheets covered much more of the Northern Hemisphere. In the future it will surely continue to evolve. In part the evolution will be driven by natural causes, such as slow changes in the Earth's orbit over many thousands of years. But future climatic change, unlike that of the past, will probably have another source as well: human activities. We may already be feeling the climatic effects of having polluted the atmosphere with gases such as carbon dioxide.

How can human societies prepare for so uncertain a climatic future? Clearly it would help to be able to predict that future in some detail, but therein lies a problem: the processes that make up a planetary climate are too large and too complex to be reproduced physically in laboratory experiments. Fortunately, they can be simulated mathematically with the help of a computer. In other words, instead of actually building a physical analogue of the land-ocean-atmosphere system, one can devise mathematical expressions for the physical principles that govern the system -- energy conservation, for example, and Newton's laws of motion -- and then allow the computer to calculate how the climate will evolve in accordance with the laws. Mathematical climate models cannot simulate the full complexity of reality. They can, however, reveal the logical consequences of plausible assumptions about the climate. At the very least they are a big step beyond purely speculative "hand waving" (see Schneider 1987, from which much of this testimony is derived).

Mathematical models have been used to simulate the present climate -- to study, for instance, the effects on the atmosphere of volcanic eruptions such as El Chichon. They are also helping to explain the evolution of past climates, including those of the ice ages and the Cretaceous period (the final age of the dinosaurs). The accuracy of paleoclimatic simulations in turn lends confidence to workers who employ the same models to simulate future climates, and who in particular try to gauge the potential impacts of human pollution. In this context climate modeling is emerging as a field of more than academic interest: it is becoming a fundamental tool for assessing public policy.

Basic Elements

Although all climate models consist of mathematical representations of physical processes, the precise composition of a model and its complexity depends on the problem it is designed to address. In particular they depend on how long a period of the past or future is to be simulated. Some of the processes that influence climate are very slow: the waxing and waning of glaciers and forests, for example, or the motions of the earth's crust, or the transfer of heat from the surface of the ocean to its deeper layers. A model designed to forecast next week's weather ignores these variables, treating their present values (the extent of ice coverage, for instance) as external, unchanging "boundary conditions." Such a model simulates only atmospheric change. On the other hand, a model designed to simulate the dozen or so ice ages and interglacial periods of the past million years must include all the above processes and more.

Climate models vary also in their spatial resolution, that is, in the number of dimensions they simulate and the amount of spatial detail they include. An example of an extremely simple model is one that calculates only the average temperature of the earth, independent of time, as an energy balance arising from the earth's average reflectivity and the average "greenhouse" properties of the atmosphere. Such a model is zero-dimensional: it collapses the real temperature distribution on the earth to a single point, a global average. In contrast, three-dimensional climate models reproduce the way temperature varies with latitude, longitude, and altitude. The most sophisticated of them are known as general-circulation models (GCMs). They predict the evolution with time not only of temperature but also of humidity, wind speed and direction, soil moisture, and other variables.

General circulation models are usually more comprehensive than simpler models in terms of the detail they include, but they are also much more expensive to design and run. The optimal level of complexity for a model depends on the problem and on the resources available to address it; more is not necessarily better. Often it makes sense to attack a problem first with a simple model and then employ the results to guide research at higher resolution. Deciding how complicated a model to use for a given task involves a trade between completeness and accuracy versus tractability and economy. This tradeoff often is more a value judgment based on scientific intuition than a judgment based strictly on scientific method.

Grids and Parameters

Even the most complex GCM is sharply limited in the amount of spatial detail it can resolve. No computer is fast enough to calculate climatic variables everywhere on the earth's surface and in the atmosphere in a reasonable length of time. Instead, calculations are executed at widely spaced points that form a three-dimensional grid at and above the surface. The model my colleagues and I at the National Center for Atmospheric Research use is typically run with a grid with nine layers stacked to an altitude of about 30 kilometers. The horizontal spacing between grid points is roughly 4.5 degrees of latitude and 7.5 degrees of longitude.

The wide spacing creates a problem: many important climatic phenomena are smaller than an individual grid box. Clouds are a good example. By reflecting a large fraction of the incident sunlight back to space or efficiently absorbing and emitting thermal infrared radiant energy, they help to determine the temperature on the earth. Predicting changes in cloudiness is therefore an essential part of reliable climate simulation. Yet no global climate model now available or likely to be available in the next few decades has a grid fine enough to resolve individual clouds, which tend to be a few kilometers rather than a few hundred kilometers in size.

The solution to the problem of sub-grid-scale phenomena is to represent them collectively rather than individually. The method for doing so is known as parameterization. It consists, for example, in searching through climatological data for statistical relations between variables that are resolved by the grid and ones that are not. For instance, the average temperature and humidity over a large area (the size of one grid box, say) can be related to the average cloudiness over the same area; to make the equation work one must introduce parameters, or proportionality factors, that are derived empirically from the temperature and humidity data or from a higher resolution process model. Since a GCM can calculate the temperature and humidity in a grid box from physical principles, it can predict through a parameterization the average cloudiness in the grid box even though it cannot predict individual clouds.

To fully simulate the climate the models must take into account the complex feedback mechanisms that influence it. Snow, for example, has a destabilizing, positive-feedback effect on temperature: when a cold snap brings a snowfall, the temperature tends to drop further because snow, being highly reflective, absorbs less solar energy than bare ground. This process has been parameterized fairly well in climate models. Unfortunately other feedback loops are not as well understood. Again clouds are a case in point. They often form over warm, wet areas of the earth's surface, but depending on the circumstances they may have either a stabilizing, negative-feedback effect (cooling the surface by blocking sunlight) or a positive one (warming the surface further by trapping heat). (For example, see Ramanathan et al. 1989.)

Climate Sensitivity

Uncertainty about the nature of important feedback mechanisms is one reason the ultimate goal of climate modeling -- forecasting reliably the future of key variables such as temperature and rainfall patterns -- is not yet realizable. Another source of uncertainty that is external to the models themselves is human behavior. To forecast, for example, what impact carbon dioxide emissions will have on climate one would need to know how much carbon dioxide is going to be emitted.

What the models can do is analyze the sensitivity of the climate to various uncertain or unpredictable variables. In the case of the carbon dioxide problem one could construct a set of plausible economic, technological and population-growth scenarios and employ a model to evaluate the climatic consequences of each scenario. Climatic factors whose correct values are uncertain (such as parameters in the cloud-feedback parameterization) could be varied over a plausible range of values. The results would indicate which of the uncertain factors is most important in making the climate sensitive to a carbon dioxide buildup; one could then focus research on those factors. The results would also give some idea of the range of climatic futures to which societies may be forced to adapt. How to respond to such information, of course, is a political issue.

Perhaps the most perplexing question about climate models is whether they can ever be trusted enough to provide grounds for altering social policies, such as those governing carbon dioxide emissions (e.g., see the overview by Schneider 1989a). How can models so fraught with uncertainties be verified? There are actually several methods. None of them is sufficient on its own, but together they can provide significant (albeit largely circumstantial) evidence of a model's credibility.

The first method is to check the model's ability to simulate today's climate. The seasonal cycle is one good test because the temperature changes involved are large -- several times larger, on the average, than the change from an ice age to an interglacial period. General-circulation models do remarkably well at mapping the seasonal cycle, which strongly suggests they are on the right track (see, for example, Figure 1). The seasonal test is encouraging as a validation of "fast physics" such as cloudiness changes. However, it does not indicate how well a model simulates slow processes, such as changes in deep ocean circulation, that may have important long-term effects.

A second method of verification is to isolate individual physical components of the model, such as its parameterizations, and test them against a high resolution sub-model or real data from the field. For example, one can check whether the model's parameterized cloudiness matches the level of cloudiness appropriate to a particular grid box. Or, one can test a GCM grid cloudiness against an isolated mesoscale model. The problem with the former test is that it cannot guarantee that the complex interactions of many individual model components are properly treated. The GCM may be good at predicting average cloudiness but bad at representing cloud feedback. In that case the simulation of the overall climatic response to, say, increased carbon dioxide is likely to be inaccurate.

A third method for determining overall, long-term simulation skill is the model's ability to reproduce the diverse climates of the ancient earth (e.g., Barron and Hecht 1985; Berger et al. 1984; Schneider 1987) or even of other planets (e.g., Kasting et al. 1988). Paleoclimatic simulations of the Mesozoic Era, glacial/interglacial cycles, or other extreme past climates help in understanding the coevolution of the earth's climate with living things. As verifications of climate models, however, they are also crucial to estimating both climatic and biological future.

Overall validation of climatic models thus depends on constant appraisal and reappraisal of performance in the above categories. Also important are a models' response to such century-long forcings as the 25 percent increase in carbon dioxide and other trace greenhouse gases since the Industrial Revolution. Indeed, most climatic models are sensitive enough to predict warming of at least 1°C should have occurred during the past century. The precise "forecast" of the past 100 years also depends upon how the model accounts for such factors as changes in the solar constant or volcanic dust (e.g., see Schneider and Mass 1975; Gilliland and Schneider 1984; or Hansen et al. 1981). Indeed, as recent data shows, the typical prediction of a degree C warming is broadly consistent but somewhat larger than observed. Possible explanations for the discrepancy include (see Schneider 1989a): (i) the state-of-the-art models are too sensitive to increases in trace greenhouse gases by a rough factor of 2; (ii) modelers have not properly accounted for such competitive external forcings as volcanic dust or changes in solar energy output; (iii) modelers have not accounted for other external forcings such as regional tropospheric aerosols from agricultural, biological, and industrial activity; (iv) modelers have not properly accounted for internal processes that could lead to stochastic or chaotic behavior; (v) modelers have not properly accounted for the large heat capacity of the oceans taking up some of the heating of the greenhouse effect and delaying, but not ultimately reducing, warming of the lower atmosphere; (vi) both present model forecasts and observed climatic trends could be consistent since models are typically run for equivalent doubling of carbon dioxide whereas the world has only experienced a quarter of this increase and nonlinear processes have been properly modeled and produced a sensitivity appropriate for doubling but not for 25% increase; and (vii) the incomplete and inhomogeneous network of thermometers has underestimated actual global warming this century.

Despite this list of excuses why observed global temperature trends in the past century and those anticipated by most GCMs disagree somewhat, the two-fold discrepancy is still encouraging. Most climatologists do not yet proclaim the observed temperature records to have been caused beyond doubt by the greenhouse effect. Thus, a greenhouse effect signal cannot yet be said to be unambiguously detected in the record. It is possible that the observed trend and the predicted warming could still be chance occurrences. One cannot easily rule out that other factors, such as solar constant variations or volcanic dust, simply have not been adequately accounted for over the past century -- except during the past decade when adequate instruments have been measuring them. Nevertheless, this empirical test of model predictions against a century of observations certainly is consistent to a rough factor of 2. This test is reinforced by the good simulation by most climatic models of the seasonal cycle, diverse ancient paleoclimates, hot conditions on Venus, cold conditions on Mars (both well simulated), and the present distribution of climates on earth. When taken together, these verifications provide a strong circumstantial case that the modeling of sensitivity of the global surface air temperature to greenhouse gases is probably valid within roughly two-fold. Another decade or two of observations of trends in earth's climate, of course, should produce signal-to-noise ratios sufficiently obvious that almost all scientists will know whether present estimates of climatic sensitivity to increasing trace gases have been predicted well or not.

The Modern Greenhouse

There is no doubt that the concentration of carbon dioxide in the atmosphere has been rising; it is roughly 25 percent higher now than it was a century ago. It is also broadly accepted that when the carbon dioxide concentration rises, the temperature at the Earth's surface must rise too. Carbon dioxide is relatively transparent to visible sunlight, but it is more efficient at absorbing the long-wavelength, infrared radiation emitted by the Earth. Hence it tends to trap heat near the surface. That is the greenhouse effect, and its existence is not questioned. It explains the very hot temperatures on Venus (whose thick atmosphere is mostly carbon dioxide) as well as the frigid conditions on Mars (whose carbon dioxide atmosphere is very thin).

What is not a consensus is the precise amount of warming and the regional pattern of climatic change that can be expected of the Earth from a specific increase in the atmospheric concentration of carbon dioxide and other greenhouse gases. (The cumulative effect of chlorofluorocarbons, nitrogen oxides, ozone and other trace gases could be comparable to that of carbon dioxide over the next century -- Ramanathan, Cicerone, Singh, and Kiehl 1985.)

It is this regional pattern of changes in temperature, precipitation and soil moisture that will determine what impact the greenhouse effect will have on ecosystems, agriculture and water supplies.

A number of workers have attempted to model the possible climatic impacts of carbon dioxide. Most of them have followed the same approach: they give the model an initial jolt of carbon dioxide (usually doubling the atmospheric concentration), allow it to run until it reaches a new thermal equilibrium and then compare the new climate to the control climate. In one of the most widely cited results, Syukuro Manabe and Richard T. Wetherald (1986) of the Geophysical Fluid Dynamics Laboratory at Princeton University have found that both a doubling and a quadrupling of atmospheric carbon dioxide would produce a summer "dry zone" in the North American grain belt, but that soil moisture in the monsoon belts would increase. Such a dry zone would substantially reduce corn yields in the Corn Belt or lake levels in the Great Lakes (e.g., Smith and Tirpak 1988). The G.F.D.L. model reached its new equilibrium after several decades of simulated time.

In reality, however, the approach to equilibrium would probably be much slower. This version of the G.F.D.L. model omitted both the horizontal transport of heat in the ocean and the vertical transport of heat from the well-mixed surface layer to the ocean depths. Both processes would slow the approach to thermal equilibrium; the real transition would probably take more than a century. Heat transport in the oceans would also affect the temperature response to a realistic, gradual increase in greenhouse gases, as opposed to the one-time injection.

Schneider and Thompson (1981) developed simple one-dimensional models that demonstrated the importance of the transient phase of warming. Regions at different latitudes approach equilibrium at different rates, essentially because they include different amounts of land; land warms up faster than the oceans. Also, oceans have different vertical mixing rates at different locations. Hence during the transient phase, the warming and other climatic effects induced by the enhanced greenhouse effect could well display world-wide patterns significantly different from the ones inferred on the basis of equilibrium GCM simulations. Furthermore, the social impact of climatic changes would probably be greatest before equilibrium has been reached and before human beings have had a chance to adapt to their new environment.

To represent the transient phase adequately one would need to couple a three-dimensional model of the atmosphere with a three-dimensional model of the ocean that includes the effects of horizontal and vertical heat transport. A handful of coupled models have been run, but none for long enough to simulate the next century (e.g., Bryan, Manabe, and Spelman 1988; Washington and Meehl 1989). The coupled models are still too uneconomical for that task, and they are also not yet trustworthy enough. Once they have been improved, one will be able to state with more confidence how the climatic impacts of rising levels of greenhouse gases might be distributed in space and time. Until then one can only cite circumstantial evidence that the impacts are likely to be significant: e.g., the present GCMs simulate past climates or the present seasonal cycle well, or the Earth is already about 0.5 degrees C warmer than it was a century ago, or the 1980s are the warmest decade on record.

Society is thus faced with a classic example of the need to make decisions with imperfect information. Some projected climatic impacts appear severe; but perhaps these could be mitigated if we know what to expect and if we choose to respond. At the same time, there is a risk of investing resources to prevent an impact that may not appear, or that may appear where least expected -- as the Antarctic "ozone hole" exemplifies. The need to know details about the timing and distribution of future climate changes has been stated in many scientific and political forums, and detailed climate impact studies have been commissioned.

In an effort to shed some light on these questions, Schneider, Gleick, and Mearns (1989) offered a set of "forecasts" on changes in some important meteorological variables, over a range of temporal, spatial, and statistical scales. I believe that carefully qualified, explicit scenarios of plausible future climatic changes are preferable to impact speculations based on implicit or casually-formulated forecasts. Therefore I include Table 1 to provide impact assessment specialists with ranges of climate changes that reflect our interpretation of state-of-the-art modeling results. These projections are based on our analysis of available results and provide what I believe are plausible estimates about the direction or magnitude of some important anthropogenic climatic changes over the next 50 years or so--a typical estimate for an equivalent doubling of carbon dioxide--together with a simple high, medium, or low level of confidence for each variable. (By "equivalent doubling", it is meant that carbon dioxide together with other trace greenhouse gases have a radiative effect equivalent to doubling the pre-industrial value of carbon dioxide from about 280 ppm to 560 ppm.) As another measure of the nature of the uncertainties, a rough estimate is included of the time that may be necessary to achieve a widespread scientific consensus (not unanimity which is unachievable) on the direction and magnitude of the change. In some cases--such as the magnitude and direction of changes in sea level and global annual-average temperature and precipitation--such a consensus is building rapidly. In other cases, such as the changing extent of cloud cover, time-evolving patterns of regional precipitation, or the daily, monthly, or interannual variance of many climatic variables, the large uncertainties surrounding present projections will only be reduced with considerably more research -- probably taking many decades at present levels of effort.

Let us consider, for example, the first row on Table 1: temperature change. The global average change of +2 to +5 degrees C is typical of that in most national and international assessments for an equivalent doubling of greenhouse gases, neglecting transient delays. The neglect of transients means that the range given is based on the assumption that trace gases have been increased over a long enough period for the climate to come into equilibrium with the increased concentration of greenhouse gases. In reality, the large heat capacity of the oceans will delay realization of most of the equilibrium warming by perhaps many decades. This implies, I said earlier, that at any specific time when we reach an equivalent CO_2 doubling (by say 2030), the actual global temperature increase may be considerably less than the +2 to +5 degrees C listed in Table 1. However, this "unrealized warming" (e.g. see Hansen et al. 1985) will eventually be experienced when the climate-system thermal response catches up to the greenhouse-gas forcing.

Forecasts of regional- or watershed-scale changes in temperature, evaporation, or precipitation are most germane to impact assessment. But, as Table 1 suggests, such regional forecasts are much more uncertain than global equilibrium projections. Regional temperature ranges given in Table 1 are much larger than global changes, and even allow for some regions of negative change. For example, higher northern latitude surface temperature increases are up to several times larger than the global average response, at least in equilibrium. Because of the importance of regional or local impact information, techniques need to be developed to evaluate smaller-scale effects of large-scale climatic changes. (For example, Gleick 1987, employed a regional hydrology model driven by large-scale climate change scenarios from various GCM inputs.)

Even more uncertain than regional details, but perhaps most important, are estimates for measures of climatic variability such as the frequency and magnitude of severe storms, enhanced heat waves, or reduced frost probabilities (e.g., Mearns et al. 1984 or Parry and Carter 1985). For example, some modeling evidence suggests that hurricane intensities will increase with climatic changes (Emanuel 1987). Such issues are just now beginning to be considered and evaluated from equilibrium climate-model results, and will, of course, have to be studied again for realistic transient cases to be of maximum value to impact assessors.

Another uncertainty raised by the transient nature of the actual trace gas forcing is the emission and removal rates of CO_2, CH_4, and other greenhouse gases. Figure 2 shows three plausible scenarios based on high, medium, and low emission rates. These uncertainties have been added to those associated with estimates of climate sensitivity and the delay associated with oceanic heat capacity. It is impossible to objectively assign probabilities to each of these three curves, but I can offer my intuitive estimates: the high and low scenarios are not too likely (say, a 10% chance each) and everything in between much more likely. In any case, since the earth has apparently not experienced global average temperatures more than 1-2 degrees C warmer than at present over the past glacial cycle (150,000 years), all but the slowest scenario in Fig. 2 represents a rapid, large climatic change to which the environment and society will have to adapt.

The principal technical advance needed to help build consensus on the reliability of time-evolving regional forecasts of hydrological variables is the development, testing, and verification of coupled atmosphere/ocean/land/biota models, driven by realistic transient trace gas forcing scenarios. Fortunately, there has been recent progress in the development of such models (e.g., Washington and Meehl 1989; Bryan et al. 1988), although it is suggested in Table 1 that it will be at least a decade before high confidence in the reliability of regional forecasts will achieve a large scientific consensus. (Personally, I think several decades is a more realistic estimate.) A greatly enhanced and better coordinated modeling and observational initiative will be needed if this several-decade time frame I estimate before credible regional scenarios can be produced is to be accelerated.

Some scientists may object in principle to the approach taken in Table 1, arguing that since the confidence levels cited are intuitive, they may be incorrect, or even that some eventual change could be in the opposite direction of that listed. Indeed, predictions about something as complex as the global climate system response to forcings controlled by human behavior will always be somewhat uncertain. Nevertheless, many policy makers are likely to have a contrasting reaction--the information in Table 1, even if certain, may still not contain enough detail to justify major policy decisions. Policy analysts typically want regional details even finer than those typically available -- e.g., those that have been provided on maps given in the survey article by Schlesinger and Mitchell (1987), a few of which are reproduced here as Figs. 3, 4, 5, and 6. This schism -- between some scientists' reticence to make any forecasts and some policy analysts' insistence on high levels of regional detail -- cannot be resolved simply by having the latter fashion their own speculative or implicit scenarios for impact assessment. Rather, I believe, it is better to have knowledgeable scientists putting forth a range of plausible "forecasts" based on the best available information.

As the state-of-the-art evolves, such scenarios will need to be regularly revised and improved, and the implications for environmental and societal impacts reassessed. Through this iterative process climate scientists hope that clearer understanding of potential climatic impacts will develop. Of course, while scientists study and debate, the world becomes committed to a growing dose of greenhouse gases and their impacts. The rates at which anthropogenic climate change could be evolving (as in Fig. 2) are extremely rapid when compared to most paleoclimatic trends (see Schneider 1989b). It is questionable whether natural ecosystems and human activities can adapt easily to such plausible rates of change, suggesting some urgency for accelerating the rate at which the scientific community is likely to resolve uncertainties in climatic scenarios and impact assessments.

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TABLE 1

PHENOMENA	PROJECTION OF PROBABLE GLOBAL ANNUAL AVERAGE CHANGE (1)	DISTRIBUTION OF CHANGE					CONFIDENCE OF PROJECTION		ESTIMATED TIME FOR RESEARCH THAT LEADS TO CONCENSUS (YEARS)
		REGIONAL AVERAGE	CHANGE IN SEASONALITY	INTERANNUAL* VARIABILITY	SIGNIFICANT TRANSIENTS	GLOBAL AVERAGE	REGIONAL AVERAGE	
TEMPERATURE	+2 TO +5 C	-3 TO +10 C	YES	DOWN?	YES	HIGH	MEDIUM	0 TO 5
SEA LEVEL	+10 TO +100 cm	(2)	NO	???	UNLIKELY	HIGH	MEDIUM	5 TO 20
PRECIPITATION	+7 TO +15%	-20 TO +20%	YES	UP?	YES	HIGH	LOW	10 TO 50
DIRECT SOLAR RADIATION	-10 TO +10%	-30 TO +30%	YES	???	POSSIBLE	LOW	LOW	10 TO 50
EVAPOTRANSPIRATION	+5 TO +10%	-10 TO +10%	YES	???	POSSIBLE	HIGH	LOW	10 TO 50
SOIL MOISTURE	???	-50 TO +50%	YES	???	YES	???	MEDIUM	10 TO 50
RUNOFF	INCREASE	-50 TO +50%	YES	???	YES	MEDIUM	LOW	10 TO 50
SEVERE STORMS	???	???	???	???	YES	???	???	10 TO 50

NOTES

(1) For an "equivalent doubling" of atmospheric CO2 from the preindustrial level. These are equilibrium values, neglecting transient delays and adjustments.

??? No basis for quantitative or qualitative forecast.

(2) Increases in sea level at approximately the global rate except where local geological activity prevails.

* Inferences based on preliminary results for the U.S. of D. Rind (GISS, personal communication).

FIGURE CAPTIONS

1. A three-dimensional climate model has been used to compute the winter to summer temperature extremes all over the globe. The model's performance can be verified against the observed data shown below. This verification exercise shows that the model quite impressively reproduces many of the features of the seasonal cycle. These seasonal temperature differences are mostly larger than those occurring between ice ages and interglacials or for any plausible near-future carbon dioxide change. Although this approach cannot validate models for processes occurring on medium to long time scales (greater than 1 year), they are very encouraging for validating to a rough factor of 2 such "fast physics" parameterizations like clouds. [Source: S. Manabe and R. J. Stouffer, *J. Geophys. Res. 85*: 5529 (1980).]

2. Three scenarios for global temperature change to 2100 derived from combining uncertainties in future trace greenhouse gas projections with those of modeling the climatic response to those projections. Sustained global temperature changes beyond 2°C (3.6°F) would be unprecedented during the era of human civilization. The middle to upper range represents climatic change at a 10 to 100 times faster pace than long-term natural average rates of change. [Source: J. Jager, *Developing Policies for Responding to Climatic Change, A Summary of the Discussions and Recommendations of the Workshops Held in Villach 28 September to 2 October 1987* (WCIP-1, WMO/TD-No. 225, April 1988).]

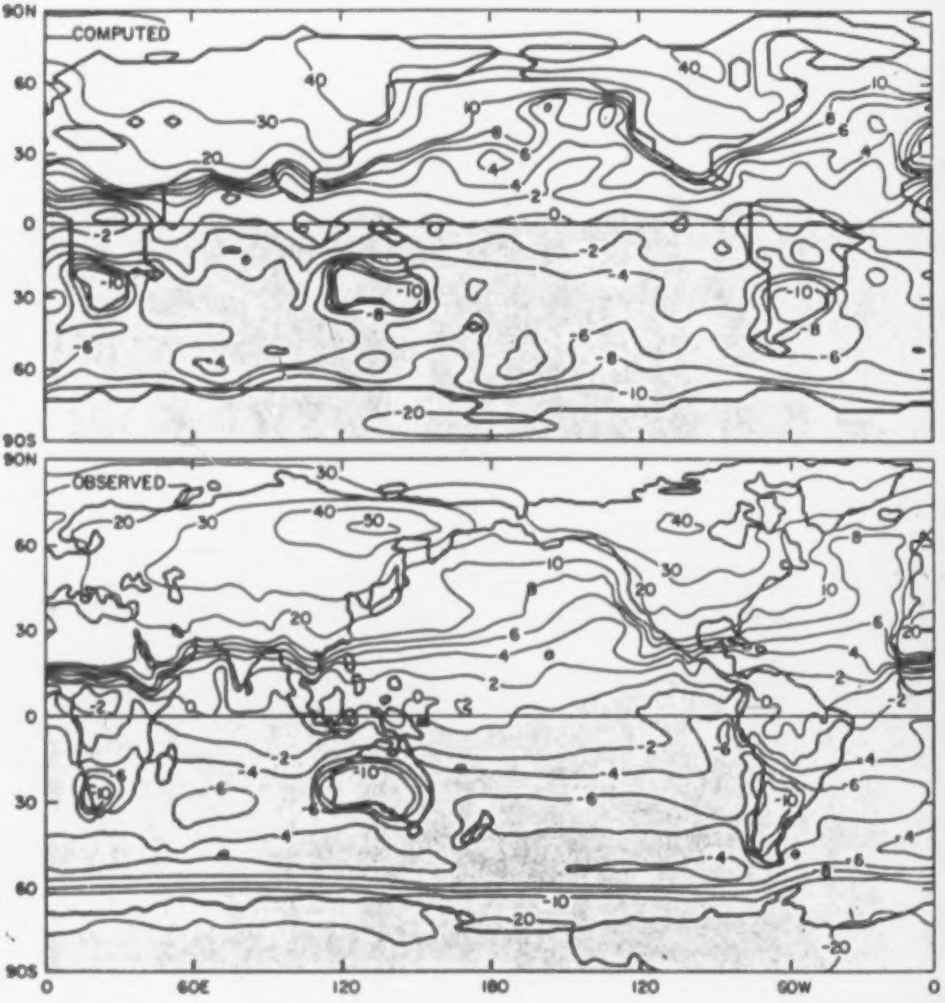
3. Geographical distribution of the surface air temperature change (in degrees Celsius), (2 x CO_2) - (1 x CO_2), for DJF simulated with (top) the GFDL GCM, (middle) the GISS GCM, and (bottom) the NCAR GCM. Stippling indicates temperature increases larger than 4°C. For reference to particular versions of the GCMs used, see M. E. Schlesinger and J.F.B. Mitchell, *Rev. Geophys. 25*:760-798 (May 1987).

4. Same as Figure 3, except for JJA.

5. Geographical distribution of the precipitation rate change (in millimeters per day), (2 x CO_2) - (1 x CO_2), for DJF simulated with (top) the GFDL GCM, (middle) the GISS GCM, and (bottom) the NCAR GCM. Stippling indicates a decrease in precipitation rate. For details of which specific GCM versions were chosen, see M. E. Schlesinger and J.F.B. Mitchell, *Rev. Geophys. 25*:760-798 (May 1987).

6. Same as Figure 5, except for JJA.

FIGURE 1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OBSERVED
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8
6
4
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-4
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-10
-20

FIGURE 2

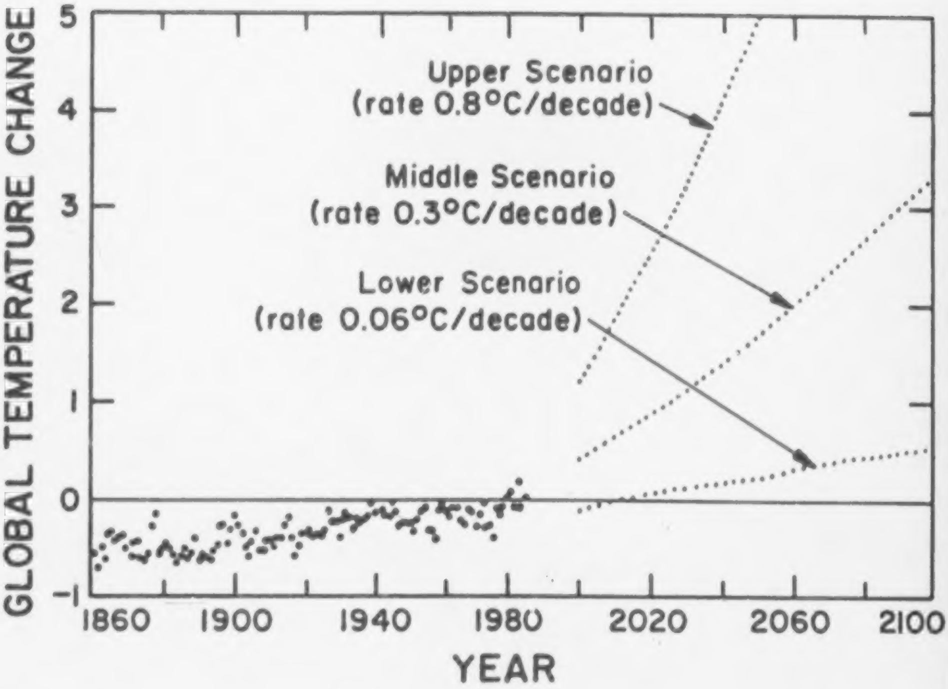
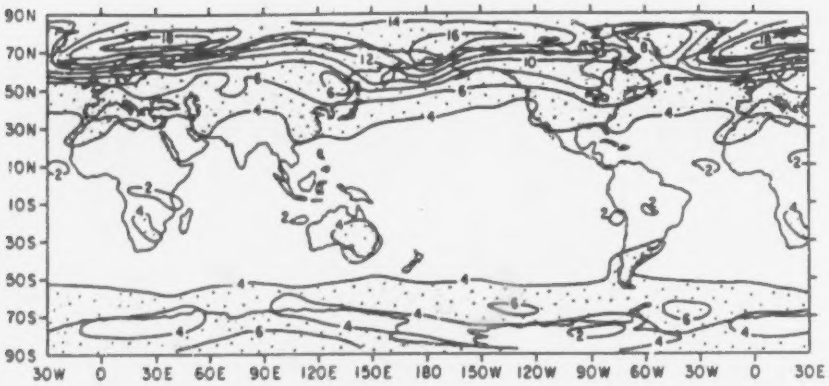

GLOBAL TEMPERATURE CHANGE
5
4
3
2
1
0
−1
1860
1900
1940
1980
2020
2060
2100
YEAR
Upper Scenario
(rate 0.8°C/decade)
Middle Scenario
(rate 0.3°C/decade)
Lower Scenario
(rate 0.06°C/decade)

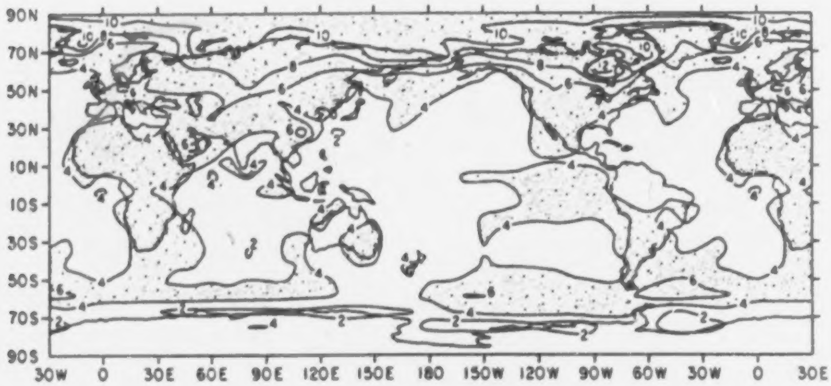
FIGURE 3

TEMPERATURE DIFFERENCES FOR DJF

GFDL, $2\times CO_2 - 1\times CO_2$



GISS, $2\times CO_2 - 1\times CO_2$



NCAR, $2\times CO_2 - 1\times CO_2$

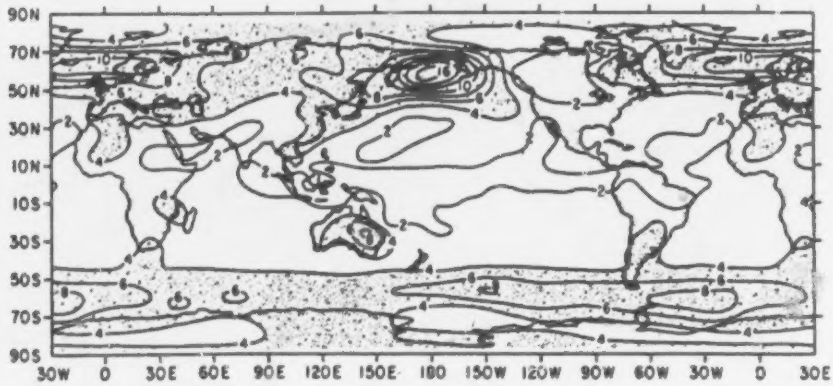
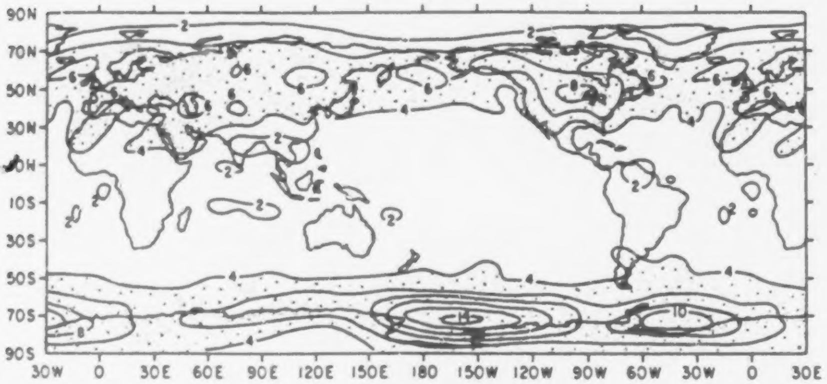


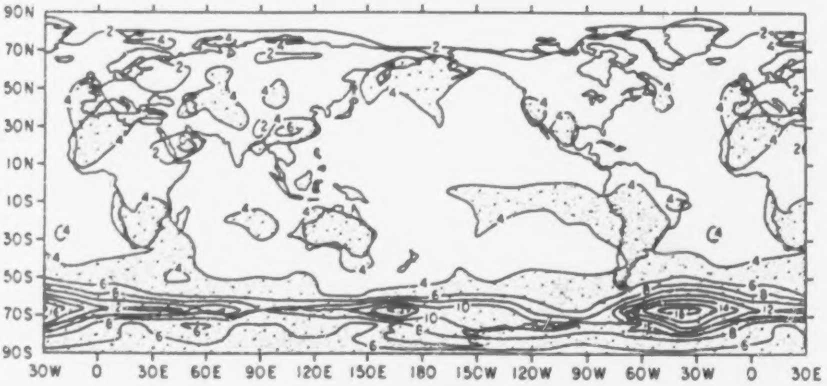
FIGURE 4

TEMPERATURE DIFFERENCES FOR JJA

GFDL, $2\times CO_2 - 1\times CO_2$



GISS, $2\times CO_2 - 1\times CO_2$



NCAR, $2\times CO_2 - 1\times CO_2$

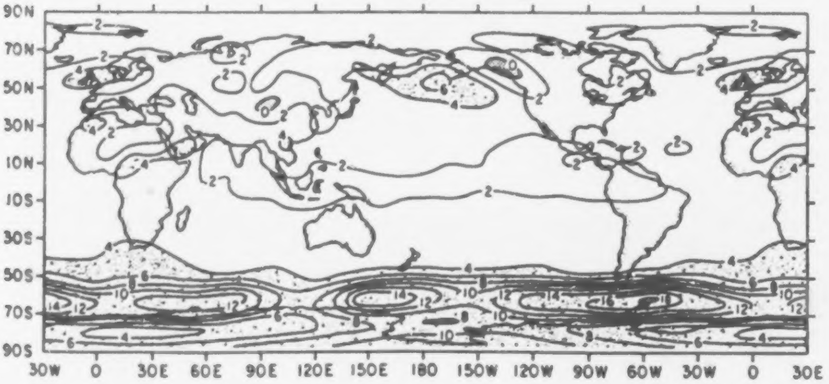
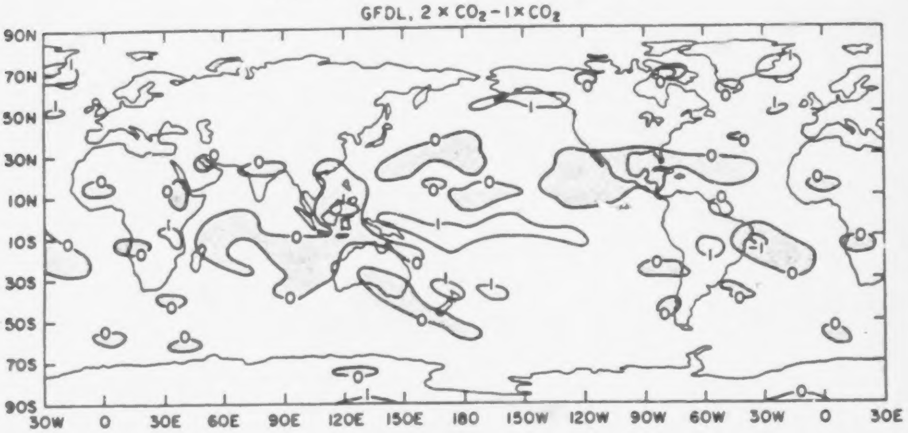


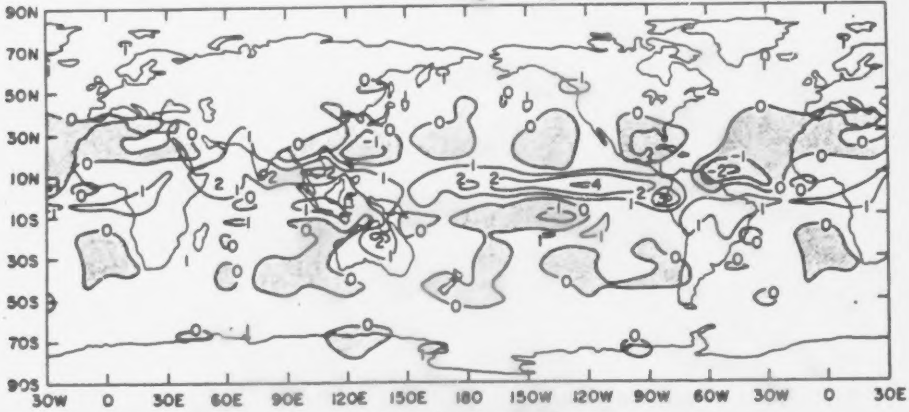
FIGURE 5

PRECIPITATION DIFFERENCES FOR DJF

GFDL, 2 × CO_2 − 1 × CO_2



GISS, 2 × CO_2 − 1 × CO_2



NCAR, 2 × CO_2 − 1 × CO_2

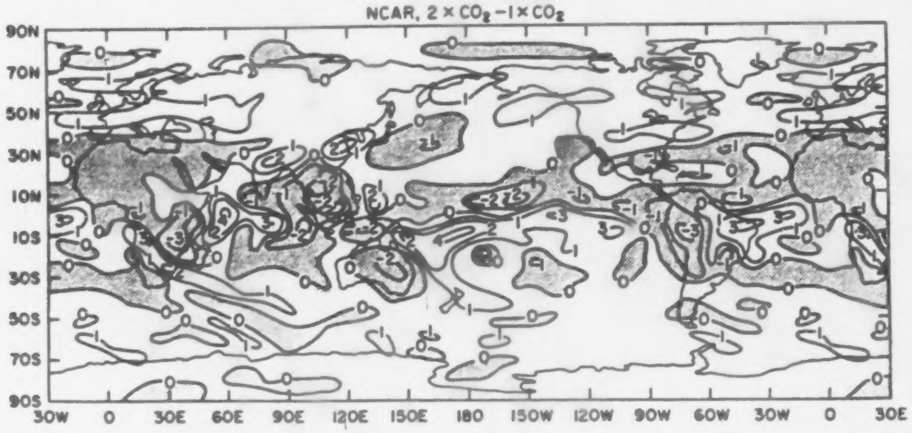
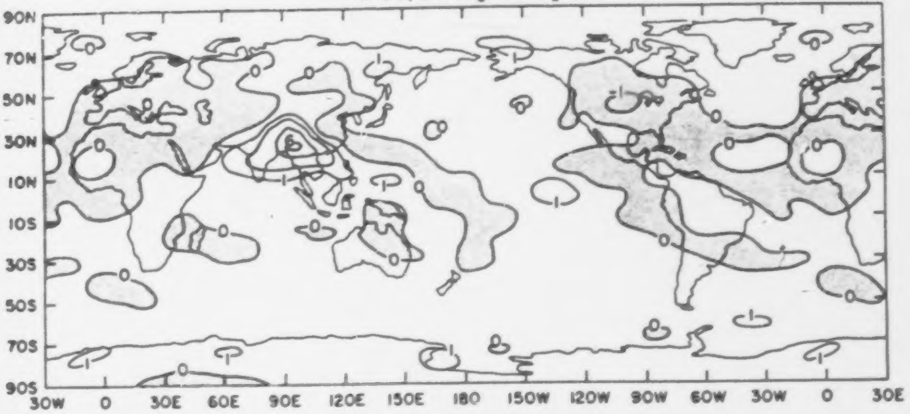


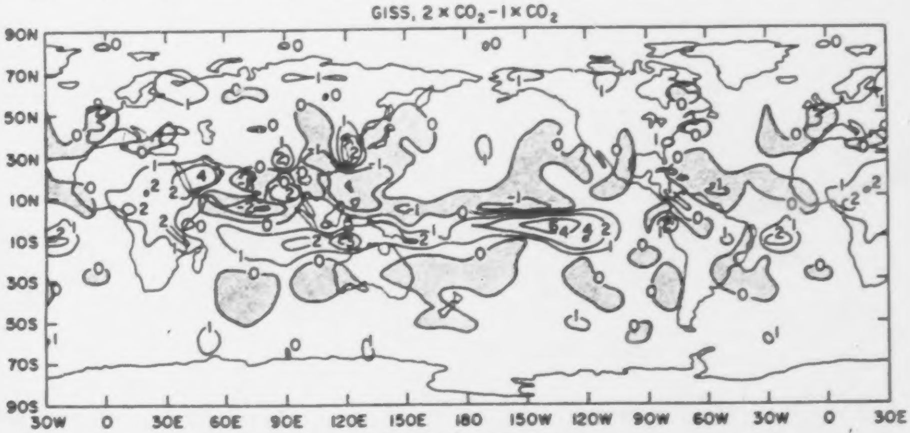
FIGURE 6

PRECIPITATION DIFFERENCES FOR JJA

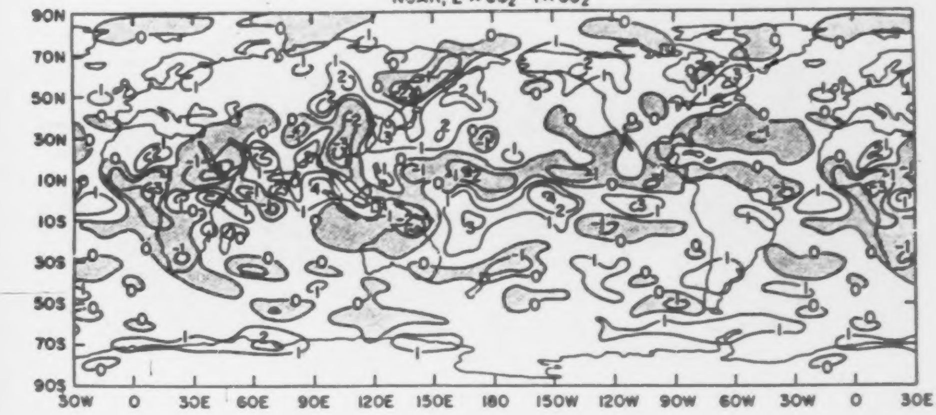
GFDL, $2\times CO_2 - 1\times CO_2$



GISS, $2\times CO_2 - 1\times CO_2$



NCAR, $2\times CO_2 - 1\times CO_2$



Senator WIRTH. Thank you very much, Dr. Schneider. Dr. Peter Gleick from Berkeley, California.

Peter.

STATEMENT OF DR. PETER H. GLEICK, DIRECTOR, ENVIRONMENT PROGRAM, PACIFIC INSTITUTE FOR STUDIES IN DEVELOPMENT, ENVIRONMENT AND SECURITY, BERKELEY, CA

Dr. GLEICK. Good morning, Senators, Lieutenant Governor. I am from the Pacific Institute for Studies in Development, Environment and Security in Berkeley, a research and policy think tank. We do a great deal of work on the issue of global climate change and also specifically on the implications of climate changes for California. Two of the members of our Board are particularly interested in this issue. Both of them have the last name of Schneider. Dr. Stephen Schneider is one of them. One of your colleagues, Representative Claudine Schneider from Rhode Island, is another. And I am going to impose on Dr. Schneider this morning to put up my view graphs for me.

I wish to commend you, first of all, for your foresight and interest in holding hearings on the implications of climate change for California and the western United States. I have submitted written testimony and some longer papers that provide a great deal more detail than I can go into this morning on the consequences of climate change for California and the western U.S.

The west and California in particular are very vulnerable to the climate changes that are coming that are caused by growing concentrations of greenhouse gases. At the same time, California is responsible for more than its fair share of greenhouse gas emissions. This poses two special problems for us. The first is, what can we do to reduce our emissions of greenhouse gases and second, what are the worst impacts that face us from climatic changes and what can be done to prepare for those impacts?

We need to do both. We need to both reduce our greenhouse gas emissions and we need to prepare for those impacts that will be most costly and damaging. Even if we can stop emitting greenhouse gases today, which of course we cannot, we will feel the impacts of those gases that we have already emitted. And, indeed, there is little evidence that serious national or international actions to reduce greenhouse gas emissions will be taken very soon.

Indeed, the few bright spots in this situation are the actions that are being taken by some of the very Senators that are here today, actions to protect our vulnerable resources and to identify policies needed to reduce our emissions. Let me first begin by discussing the California perspective, emissions of greenhouse gases from California. California emits sizable amounts of greenhouse gases, perhaps ten percent of the total U.S. emissions, but the pattern of emissions in California is quite a bit different than the pattern of emissions from the rest of the United States.

For example, we emit quite a bit less of carbon dioxide than average because very little coal is burned here. We emit more chlorofluorocarbons than average, however, because of our very extensive electronics industry, because of our heavy reliance on the automobile which both uses and leaks chlorofluorocarbons. Emissions of nitrous oxide and methane, two other greenhouse gases, are also quite large because of California's extensive agricultural production.

Steve, if I could have the first view graph and perhaps the lights down a little bit. This is a pie chart that shows U.S. emissions of carbon dioxide by fuel and California emissions by fuel. The top pie chart is the U.S. and the green is oil. The red is coal and the uncolored section is natural gas. And you can see we get most of our carbon dioxide in the United States from oil but a substantial fraction, perhaps a quarter from coal. If you look at the bottom pie chart, however, which shows California emissions, the pattern is quite a bit different. You can see we get much more of our carbon dioxide from oil and very, very little from coal, about one percent. Now, I think it is only fair to note here that California exports a little bit of its pollution. We actually get electricity that we use in California from coal fired power plants outside of the state. That is not included in these figures but it is only fair to mention it. California actually emits a little more CO_2 in other people's states including—I see Senator Wirth noticing his state as well.

Now, the second view graph shows that a far greater fraction of carbon dioxide in California comes from the transportation sector marked in yellow—sort of yellow here, dirty yellow, I guess—it is only appropriate—than the national average. And California perhaps sixty percent of our CO_2 comes from the transportation sector, whereas for the U.S. as a whole, it is just a little bit over thirty percent.

The other big difference to note here is electric utilities. The U.S. average, about thirty percent, perhaps a third of our carbon dioxide emissions comes from the electric utilities section sector. In California, it is only about eight or ten percent. And again, that is partly because California uses a great deal more renewable resources than the rest of the United States. We burn far less coal as well.

Now, emissions could be further reduced in California, in particular, but this is true of everywhere, by explicitly identifying those emissions, those energy technologies that are high greenhouse gas emitters and perhaps by including greenhouse gas emissions criteria as one of the ways we select new energy resources. And I am going to return to this point at the end.

Now, let me move on to the impacts of climate change for California. As I mentioned, California is very vulnerable to climatic changes. We have a very long coast line that is vulnerable to sea level rise. We have a multi-billion dollar agricultural industry that is very sensitive already to changes in temperature, to changes in rainfall patterns, to changes in water supply. California has a very long history of conflict over scarce and poorly distributed water resources and we have an incredibly rich natural environment that would be very adversely effected by some of the kinds of climatic changes that are likely to occur that Stephen mentioned earlier.

I would like to summarize briefly some of these important impacts. Dr. Dracup following me, will talk specifically about water resources which, in my opinion, is probably the most important impact facing California. But let me start with sea level rise. Among the most important consequences we can expect in the next several decades are the inundation of developed shoreline areas as sea level rises, the creation of inland sea, for example, in the Sacramento, San Joaquin delta, as levies fail and significant changes in our natural ecosystems.

Rising sea level will threaten fresh water supplies, reduce delta agricultural productivity and accelerate ecosystem and wetland loss. Disruption and dislocation of industrial, commercial and residential development is probable unless enormous financial resources are devoted to building and protecting the existing levies and developing other protective structures. Perhaps the most dramatic finding for California with the recent study released by the Environmental Protection Agency, was that a one meter—about a three foot rise in sea level could triple the size of the San Francisco Bay and the Sacramento/San Joaquin delta and double its volume if the current levies were allowed to fail.

If all of the levies are improved and protected, the area of the delta would still increase perhaps thirty percent and its volume would increase fifteen percent. A rising sea level, in addition, would put salt water farther up the delta toward the fresh water supply, the fresh water pumps for the California aqueduct system. This rise in sea level would also drastically alter the natural ecosystems and, in fact, the delta in San Francisco Bay have some of the few remaining rich wetlands that California once had.

Now, major gaps remain in our understanding of the impacts of a rising ocean. For example, no study has yet been done on the costs of protecting the vulnerable structures along the coast. What would be the costs of protecting the airports, such as the San Francisco and the Oakland Airport, which are both sitting in San Francisco Bay, nuclear power plants and other energy structures that have intake structures running along the coast, waste treatment plants, dock facilities, land fill sites, transportation routes such as freeways that are sitting right near the coasts.

But I think it is quite safe to say that the costs of protecting or replacing these structures would run into the tens of billions of dollars and perhaps it is time we begin doing the studies necessary to really see what exactly these costs would be. Now, water resources—as I mentioned, I think water resources is probably the most important issue facing us. California water resources are especially sensitive to climatic change. They are already sensitive to climatic variability, the natural variability we already see. And indeed, the impacts of climatic change on California water resources may be the most important and disruptive.

Just to summarize briefly, we can expect summer water demand to go up as higher temperatures begin to appear, summer water demand for agriculture, summer water demand for municipalities and for industry. Snow conditions will greatly change. There will be very simply a shorter snow season, less winter snow pack, faster and shorter spring snow melt, and I will come back to this in a second. Summer soil moisture is going to be drier. That is going to require for our agricultural situation perhaps different kinds of crops, perhaps more summer irrigation water. It may no longer make much sense to grow cotton or rice in California. We may need to begin shifting our agricultural crops to different kinds of, less water intensive crops.

Droughts may become more severe and more frequent. Perhaps the most important change is this effect on snow conditions. And let me go into that in a little more detail. Very simply, as the temperatures go up, the snow line is going to go up. This is just a schematic that shows on the bottom, perhaps the current altitude of the snow line and then the snow line increasing to a higher altitude as the temperature goes up. And the implications of this are that less of what falls in the winter is going to be snow. We may get the same amount of water in the winter overall, but less of it is going to be snow. More of it is going to be rain. What falls as rain is going to run off right away, exacerbating winter flooding and less of it is going to be available for the spring and the summer melt. As you may know, in California, we have this dilemma. We get the water in the winter. We need it in the summer. We want our reservoirs as empty as possible in the winter for flood control and yet, we want them as full as possible in the spring and the summer for the dry irrigation season.

For the Sacramento basin, the major basin in northern California—these numbers come from some of the research that I have done—and this shows very simply are for eight different scenarios from general circulation models, the change in winter runoff, December, January and February runoff, for California, looking at the temperature—looking only at changes in temperature and precipitation, really the thing to note about this quite simply is that every one of these scenarios shows big increases in winter runoff. This increases the risk of winter flooding in California and at the same time, the next view graph shows what might happen to summer runoff. And again, all of these scenarios from general circulation models for northern California, showed decreases in summer runoff. Just when we need the water the most, the water is already gone because the winter snowpack has gone earlier and what was there has run off faster.

John Dracup will go into these issues in more detail. Perhaps the big question is, can these kinds of changes be handled by the California water system? And again, the answer is we just do not know for sure, and we will not know until California agencies and Federal agencies as well, spend the time and spend the money to look at the implications for changes in runoff in California and to evaluate the implications for management of the reservoir systems for water demand for allocation of water resources, for water marketing, for water rights, for the price of water, a whole range of issues that get Californians very excited when they start to talk about them.

Let me move on to agriculture. California's agricultural resources are perhaps the richest in the world, valued at $15 billion annually. And, in fact, California dominates the U.S. agricultural production of crops, such as cotton, grapes, lettuce, tomatoes, many different kinds of fruits. Yet, we know that unusual weather conditions already lead to crop failures, changes in crop types, changes in planting patterns. If we could accurately predict the details of future climatic conditions, well, then our agricultural system would be able to adapt to the kinds of changes that are coming. Without that information, however, farmers can expect continued and even capricious climatic conditions that will greatly complicate planning and investment decisions.

The whole agricultural question is a very difficult one for California. There are very many uncertainties about changes in the timing of precipitation, changes in when and where water will be available, changes in the growing season, changes in the kinds of crops that may be available in the future. Perhaps we can develop drought resistent crops or heat resistent crops. But we are not going to know until we start to do the work. I think it is safe to say that substantial changes in agricultural practices will be necessary in order to maintain California's standing as one of the richest farming regions in the world.

These changes could include changes in crop types, changes in planting seasons, irrigation techniques, agricultural technology. Natural resources, again, as I mentioned earlier, California is very richly endowed with a tremendous range of natural resources, from Mohavian Colorado desert habitats to ocean sanctuaries to alpine Sierra ecosystems. California has four national parks, nine major national forests, thirteen designated natural wildlife refuges. California is home to a wide range of endemic flora and fauna that are threatened already with extinction due to loss of habitat or direct human activities.

Climate changes will affect natural ecosystems in many different ways. Among the greatest concerns are loss of species due to shifts in suitable habitat from one region to another as temperatures or precipitation patterns change. As the climate warms existing preserves of critical habitats may be lost entirely or may just no longer be suitable for the kinds of species that are currently protected there. Efforts to expand our park system and our ecological preserves such as of those efforts of Senator Cranston for California are even more important under conditions of the changing climate. And I applaud Senator Cranston's efforts and I wish him the best of luck in those efforts.

Studies of the impacts of climate changes on wetlands and fisheries in California have concluded that changes in species composition as Lieutenant Governor Leo McCarthy mentioned are likely in fresh water and ocean fisheries and in the mixed estuary conditions of the bay and in the delta. A summary of some of these impacts are my next view graph.

Other impacts include changes in the frequency and severity of pest outbreaks, reduced forest density, timber productivity, more demand for irrigation, for agriculture and for nature ecosystems, higher incidents of pests, I've mentioned, higher incidents of forest fires, Stephen has mentioned, is a serious problem in California. Changes in the compositions of species, degraded lake water quality, particularly in the high alpine regions of California, altered lake fish composition. There's a long list that is in my written testimony and I will not go into that in any more detail. But one more note, higher summer temperatures imply, an aggravation of ozone formation in southern California, in effect, also identified in the central valley and in northern California and I just note that higher ozone levels are bad for both natural ecosystems and for human health.

A word about energy, that is my last view graph, the primary responsibility for the production of carbon dioxide lies with our use of fossil fuels. Thus, our energy policies directly effect the rate and the severity of future climatic changes. At the same time, greenhouse warming will have several effects on our production and use of energy. Among the concerns are changes in hydroelectricity production in California and in the Pacific Northwest, where some of California's electricity is produced, higher demands for electricity for summer cooling in California, higher demand for energy for pumping irrigation water, threats to our coastal intake structures, for power plant cooling which I've mentioned, altered wind patterns, altered wind intensities, altered levels of solar insulation.

California could need substantially more capacity under conditions of greenhouse warming as our peak summer cooling demand increases. We use the most electricity. Our peak demand is in the summer when it's the hottest and it's going to be hotter. Droughts in California have the potential to drastically reduce the output of our hydroelectricity production. Just as an example, during the 1976 and 1977 drought, a very severe two-year drought—it's perhaps no longer safe to say our severest two-year drought because we've just gone through a two-year drought and this third year looks to be dry as well, but during the 1976–1977 drought, California hydroelectricity dropped from twenty percent of our total electricity supply to only seven percent and we've burned $500 million dollars more in fossil fuels to make up that lost hydro-supply, half a billion dollars, incidently burning more—adding more carbon dioxide into the atmosphere.

As concerns about climatic change grows, we may begin to see restrictions, for example, on new carbon dioxide emitting sources and an emphasis on improving energy efficiency, the development of non-CO_2 emitting energy sources such as solar, wind, hydro, nuclear and geothermal. California has always led the rest of the nation in the development of these alternatives and in my testimony, there is a table that lists some of the recent developments in renewable energy in California.

Let me close with a quick note on some solutions and some opportunities that face us. Other speakers today will address in more detail some of the necessary responses to the problem of climatic change, including the need for energy conservation and improved efficiency, the need for accelerated research and funding for renewables, and other non-carbon based energy resources, and the need to begin planning for coming changes on a state and a local level.

I am not going to add to those remarks. One more point needs to be made, however. The greenhouse effect poses grave threats to our present society, both in the United States and in particular in poor developing countries and the remarks by Senator Gore about the international implications of climatic change, I felt were right on the money. We need to begin thinking about the international implications and the international risks of conflicts over fresh water resources, over access to agricultural resources and access to other kinds of resources, population movements due to rising sea level and population displacements. These are very critical issues.

Yet some significant opportunities also exist, if we are wise enough to see them and to capitalize on them. The United States and California especially, used to be a leader in energy efficiency improvements and renewable energy technologies. In the late 1970's California led the world in building energy efficiency standards for construction, in appliance efficiency standards, and the development and deployment of wind systems, solar thermal system, photovoltaics, geothermal and cogeneration systems. We still get substantial energy from those resources in California. But funding for research on the newest systems has dropped to what I would say is a pitiful level at a time when western Europe and Japan are spending more and more to develop inexpensive photovoltaics and new energy resources that are renewable.

The world-wide market for these resources is enormous. Are we going to tap into these markets or are we going to lag behind on technical innovation and buy our photovoltaics from abroad? Perhaps the worries about climatic change will finally force us to open our eyes and to take some of the steps we should have been taking for a long time. Thank you very much.

Senator **Wirth**. Thank you for coming down and being here with us this morning.

Dr. Dracup.

[The prepared statement of Dr. Gleick follows:]

PACIFIC INSTITUTE
FOR STUDIES IN DEVELOPMENT ENVIRONMENT AND SECURITY

THE IMPACTS OF CLIMATIC CHANGES FOR CALIFORNIA: A REVIEW

Testimony of Dr. Peter H. Gleick

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May 20, 1989

for the Senate Committee on Energy and Resources
Hearing on Global Warming and Effects on California

Los Angeles, California

Testimony of Dr. Peter H. Gleick[1]

May 20, 1989

Senate Committee on Energy and Resources
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THE IMPACTS OF CLIMATIC CHANGES FOR CALIFORNIA: A REVIEW

Good day, Senators. I wish to commend you on your foresight and interest in holding hearings on the implications of climatic changes for California and the Western United States. I am submitting with my testimony two longer papers that detail the consequences for California and the Western United States of greenhouse climatic changes.

The West, and California, are very vulnerable to coming climatic changes caused by growing concentrations of greenhouse gases. At the same time, California is responsible for more than its fair share of greenhouse gas emissions. Two special issues thus face us:

First, what can we do to reduce our emissions of greenhouse gases; and

Second, what are the worst impacts that face us and what can be done to prepare for them.

We must both try to reduce our greenhouse gas emissions and to prepare for those impacts that will be most costly and damaging. Even if we could stop emitting greenhouse gases today, we will feel the impacts of those gases we have already emitted. And there is little evidence that serious national or international actions to reduce greenhouse gas emissions will be taken soon. Indeed, the few bright spots in the situation are the actions being taken by the very Senators here today--actions to protect our vulnerable resources and to identify needed policies to reduce our emissions.

EMISSIONS OF GREENHOUSE GASES: A CALIFORNIA PERSPECTIVE

California emits sizable amounts of greenhouse gases, about ten percent of total U.S. emissions. The pattern of California emissions, however, differs considerably from the national pattern of emissions. The State emits less carbon dioxide than average, for example, because very little coal is burned here. California emits more chlorofluorocarbons than average, however, because of a large electronics industry and a heavy reliance on automobiles, which use, and leak, CFCs. Emissions of nitrous oxide and methane are also sizeable because of California's extensive agricultural production.

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Tables 1 and 2 and Figures 1 and 2 show the breakdown of carbon dioxide emissions by sector and by fuel for California and the United States.

A far greater fraction of carbon dioxide comes from the transportation sector in California--nearly 60 percent, compared to a national average of 32 percent. This is one more example of the high environmental cost we pay for our dependence on the automobile. The air you're breathing today is another example. In Los Angeles, the water comes from northern California, but the air we make locally. Electric utilities nationwide account for about 33 percent of U.S. carbon dioxide emissions, while they account for only 9 percent of California's carbon dioxide emissions. Emissions of greenhouse gases from California utilities are lower than the national average for two reasons: first, very little coal is burned to provide electricity in California; and second, California has developed substantial renewable electricity sources, including hydroelectricity, geothermal, wind, and solar thermal and electric. Emissions could be further reduced by explicitly identifying high- and low-greenhouse emission technologies and including greenhouse-gas emissions among the criteria for choosing new energy sources. It must be noted that some of California's electricity is generated by power plants in other states; thus California electrical demand is responsible for slightly greater emissions of carbon dioxide than indicated by Table 1.

Table 1
Carbon Dioxide Emissions by Sector
for California and the United States

	California % of total	US Average % of total
Transport	57.7	31.8
[Gasoline	**33.7**	**20.5]**
Industrial/ Commercial	25.1	27.5
Residential	8.5	7.4
Electric Utilities*	8.7	33.3
[Coal	**0***	**28.2**
Oil	**0.8**	**3**
Gas	**7.8**	**2.2]**

* Note: Some of California's electricity is produced by coal plants located outside of the State. Thus, slightly more carbon dioxide is actually generated by the energy sector than indicated by the figures above.

Source. S. Machado and R. Piltz. 1988. "Reducing the Rate of Global Warming: The States' Role. Renew America, Washington, DC. 33pp.

Table 2
California and U.S. Carbon Dioxide Emissions by Fuel
(million tonnes carbon and percent)

	Total	Oil	Coal	Gas
California				
Million tonnes	85	61	1	23
Percent		72%	1%	27%
United States				
Million tonnes	1275	607	430	238
Percent		53%	26%	22%

(Percentages may not add to 100% due to rounding.)

Source. S. Machado and R. Piltz. 1988. "Reducing the Rate of Global Warming: The States' Role. Renew America, Washington, DC. 33pp.

CLIMATE IMPACTS: A CALIFORNIA PERSPECTIVE

California is very vulnerable to the greenhouse effect for several reasons. California has a long coastline vulnerable to sea-level rise; California has a multi-billion dollar agricultural industry sensitive to changes in temperature, rainfall, and water supply; California has a long history of conflict over scarce, poorly distributed water resources; and California has an incredibly rich natural environment that will be adversely affected by the many climatic changes likely to occur. Today I would like to summarize the most significant impacts facing us.

Sea-Level Rise

Among the important consequences we can expect in the next several decades are the inundation of developed shoreline areas, the creation of an inland sea in the Sacramento-San Joaquin Delta as levees fail, and significant changes in natural ecosystems. Rising sea level will threaten freshwater supplies, reduce Delta agricultural productivity, and accelerate ecosystem and wetland loss. Disruption and dislocation of industrial, commercial, and residential development is probable, unless enormous financial resources are devoted to building levees and other protective structures.

Perhaps the most dramatic finding for California of recent research done for the U.S. Environmental Protection Agency was that a one-meter rise in sea level would triple the size of the San Francisco Bay/Delta and double its volume if levees were allowed to fail. If all the levees were improved and maintained, the area of the Bay/Delta would still increase 30 percent and its volume would increase 15 percent. This would push salt water farther up the Delta toward the water-supply pumps for California's aqueduct system.

Major gaps remain in determining the effects on the physical geography and morphology of the Bay/Delta, on the altered risk of storm damage, and on the management of water quality in the Delta. No study has yet been done to evaluate the costs of protecting vulnerable structures along the4 coast, such as the San Francisco and Oakland airports, nuclear power plants and other energy facilities, waste treatment plants, dock facilities, landfill sites, and transportation routes such as freeways, but the cost of protecting or replacing these structures will run into the tens of billions of dollars. The cost of simply maintaining the current Delta levees from existing sea-level effects has been estimated to be over $4 billion ($ 1982) (State of California 1982).

Water Resources

California water resources are especially sensitive to future climatic changes. My research has indicated that the most significant effect on California water resources will be a rise in snowline as temperatures rise, leading to more winter runoff and less winter snowpack. What does fall as snow will run off faster in the spring and summer, leading to faster summer drying and less summer soil moisture for agriculture. Figure 3 shows the effect of higher temperatures on snowline in the Sierra. Figures 4A and 4B show the effects on seasonal runoff. Can these changes be handled by the large California water systems? We do not know, and will not find out until California agencies spend the time, money, and effort to evaluate the effects of climatic changes on state water facilities. At present, little research has been done into whether or not changes in management and operating rules can handle the seasonal changes described above.

When these changes are combined with the threats to water quality posed by rising sea level in the Delta and with rising demands from a growing population, it becomes apparent that changes are urgently needed in the way water is used, priced, traded, and subsidized.

Agriculture

California's agricultural resources are among the richest in the world--valued at nearly $15 billion annually. California dominates U.S. agriculture production of crops such as cotton, grapes, lettuce, and tomatoes. Yet we know that unusual weather already leads to crop failures and changes in crop types and planting patterns. If we can accurately predict the details of future long-term climatic changes, our agricultural industry would be able to plan how to accommodate and adjust. Without this information, however, farmers must expect continued and even capricious climatic conditions that complicate planning and investment decisions. Unfortunately, except for consistent predictions of rising temperatures, information is simply not available in sufficient detail on the response of crops to a combination of new conditions such as higher carbon dioxide concentrations, high summer temperatures, changes in water demands and water use efficiency, and changed frequency of pest outbreaks.

Some initial work has been done for the U.S. EPA on evaluating the effects of climatic changes on California agriculture. The results suggest that climatic changes will lead to major changes in crop productivity due to higher temperatures and changes in water availability. As a result, substantial changes in agricultural practices would be necessary to maintain California's standing as one of the richest farming regions in the world. For a number of reasons, the results of this study are of limited value: no national or international agricultural price signals were considered, not changes in agricultural technology or crop varieties were permitted, and no changes in planting dates or water costs were included. This area is ripe for additional careful research.

Natural Resources

In addition to being one of the richest agricultural regions in the world, California is endowed with a tremendous range of natural resources, from Mohave and Colorado desert habitats to ocean sanctuaries to alpine Sierra ecosystems. California has four National Parks, nine major National Forests, and thirteen designated National Wildlife Refuges. California is also home to a wide range of endemic flora and fauna that are threatened with extinction due to loss of habitat or direct human actions.

Climatic changes will threaten natural ecosystems in several ways. Among the greatest concerns are loss of species due to a shift in suitable habitat from one region to another. (See Figures 5 and 6.) As the climate warms, existing preserves or critical habitats may either be lost entirely or greatly reduced in scope. Efforts to expand our park system and ecological preserves, such as those of Senator Cranston, are even more important under conditions of changing climate.

Studies of the impacts of climatic changes on wetlands and fisheries in California have concluded that changes in species composition are likely in freshwater and saltwater ecosystems and in the mixed estuarine Bay and Delta. Among the greatest causes for concern are rising sea level and changing salinities in the wetlands of the Bay and Delta, and rising temperatures and water quality effects in high mountain lakes and streams. Other impacts will include changes in the frequency and severity of pest outbreaks and forest fires, and changes in vegetation patterns. California forests may suffer an expansion of chaparral at the expense of southern oak and blue-oak/digger pine woodland, an extension of yellow pine, mixed conifer forest to higher elevations at the expense of subalpine forests, and the expansion of inland prairie and sage at the expense of coastal sage and succulent vegetation in southern California. Higher summer temperatures imply an aggravation of ozone formation in southern California, an effect also identified for the Central Valley in northern California. Higher ozone levels are bad for both natural ecosystems and human health.

Electric Utilities and Energy Resources

The primary responsibility for the production of carbon dioxide lies with our use of fossil fuels. Thus our energy policies directly affect the rate and severity of future climatic changes. At the same time, greenhouse warming will have several effects on our production and use of energy. Among the concerns are changes in hydroelectric production both in California and in the Pacific Northwest, where some of California's electricity is produced, higher demands for electricity for summer cooling and lower winter heating demands, higher demand for energy for pumping irrigation water in summer, threats to coastal intake structures for power plant cooling, and altered wind patterns and intensities and levels of solar insolation.

California could need substantially more capacity under conditions of greenhouse warming due to increases in peak summer cooling demand. And droughts in California have the potential to dramatically reduce the output of the state's hydroelectric plants at a substantial cost for replacement energy. During the 1976-1977 drought, for example, over $500 million worth of extra fossil fuel had to be burned in California to make up for lost hydroelectricity.

As concern about climatic changes grows, we may begin to see restrictions on new carbon-dioxide emitting sources and an emphasis on improving energy efficiency and the development of non-CO_2 emitting energy sources such as solar, wind, hydro, nuclear, and geothermal. Indeed, the recent international conference on the global atmosphere held in Toronto recommended a 20-percent cut in global carbon dioxide emissions by the year 2005, to be accomplished half through energy-efficiency improvements, and half through the development of new, non-fossil-fuel resources. California has always led the rest of the nation in the development of these alternatives. Table 3 lists the recent additions of new solar, wind, geothermal, and cogeneration energy systems installed in California since 1979 by third-party power producers.

Table 3

Alternative Energy Projects in California (MWe)
1979-1988 [2]

	On Line [1]	Under Contract
Solar	147	454
Wind	1350	2705
Geothermal	312	594
Cogeneration and Biomass	3816	5584

Note.

1. All of these projects are third-party power producers. In addition to these, substantial capacity owned by utilities is already on-line, particularly in the geothermal sector.

2. Source: IEP (1988).

SOLUTIONS AND OPPORTUNITIES

Other speakers today will address in detail some of the necessary responses to the problem of climatic change, including the need for energy conservation and improved efficiency, the need for accelerated research and funding for renewable and other non-carbon based energy resources, and the need to begin planning for coming changes on a state and local level. I will not add to these remarks.

One more point needs to be made, however. The greenhouse effect poses grave threats to our present society, both in the United States and especially in poorer, developing countries. Yet some significant opportunities also exist, if we are wise enough to see them and to capitalize on them. The United States, and California especially, used to be a leader in energy-efficiency improvements and renewable-energy technologies. In the late 1970s, California led the world in building energy standards for construction, in appliance-efficiency standards, in the development and deployment of wind systems, solar-thermal systems, photovoltaics, geothermal, and cogeneration. We still get substantial energy from these resources. But funding for research on the newest systems has dropped to a pitiful level, at a time when Western Europe and Japan are spending more and more to develop inexpensive photovoltaics and new renewable energy sources. The worldwide market for these resources is enormous. Are we going to tap into these markets? Or are we going to lag behind on technical innovation and buy our photovoltaics from abroad? Perhaps the worries about climatic change will finally force us to open our eyes and take some steps we should have been taking for a long time.

Thank you and I will be happy to answer questions.

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CAPTIONS

Figure 1. U.S. and California carbon dioxide emissions by sector. (From: Machado and Piltz, 1988.)

Figure 2. U.S. and California carbon dioxide emissions by fuel. (From: Machado and Piltz, 1988.)

Figure 3. The rise in snowline under conditions of greenhouse warming. This effect will lead to greater winter runoff and less spring and summer snowpack runoff.

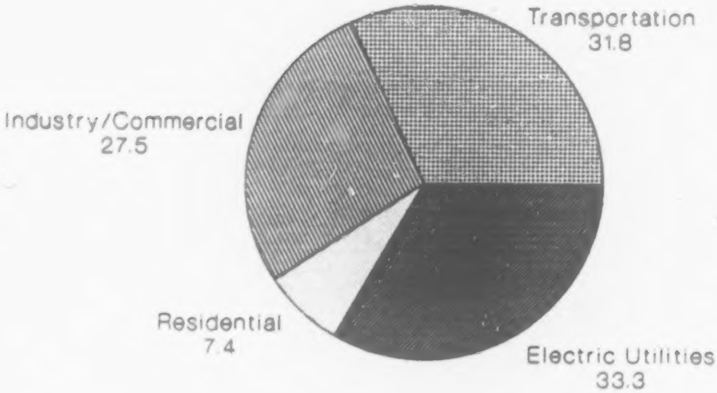
Figure 4A. The change in monthly average runoff in the Sacramento Basin using the temperature estimated by the Geophysical Fluid Dynamics Laboratory (GFDL) for a doubling of carbon dioxide in the atmosphere. Note the large increase in winter runoff and the large decrease in spring and summer runoff due to changes in snowfall and snowmelt conditions. (Source: Gleick 1987.)

Figure 4B. The percent change in monthly average runoff in the Sacramento Basin using the 2 x CO_2 temperature estimates of the Geophysical Fluid Dynamics Laboratory (GFDL) climate model. Note the large increase in winter (December, January, February) runoff and the large decrease in spring and summer runoff due to changes in snowfall and snowmelt conditions. (Source: Gleick 1987.)

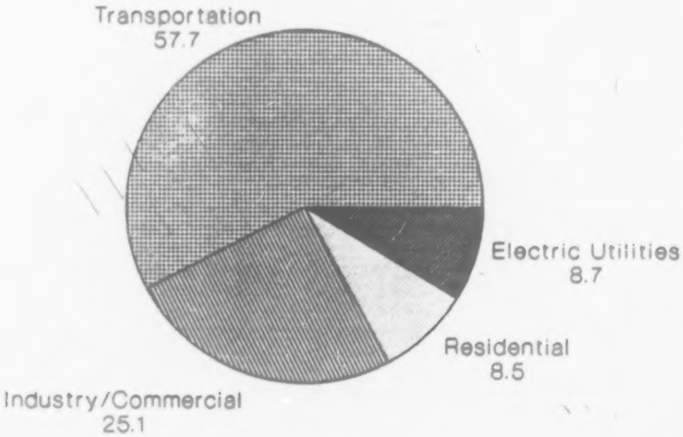
Figure 5. (A) Initial distribution (by altitude) of three species, A,B,C. (B) Distribution after a rise in temperature. Note displacement (and complete elimination) of species A by species B; displacement of species B by species C; and colonization by species D. (From: Peters 1988.)

Figure 6. Changes in biological reserves due to climate change. "SL" refers to southern limit of species range. This figure shows how today's biological reserves may become unsuitable for present species under new climatic conditions. (From: Peters 1988.)

U.S. CARBON DIOXIDE EMISSIONS BY SECTOR
Percent

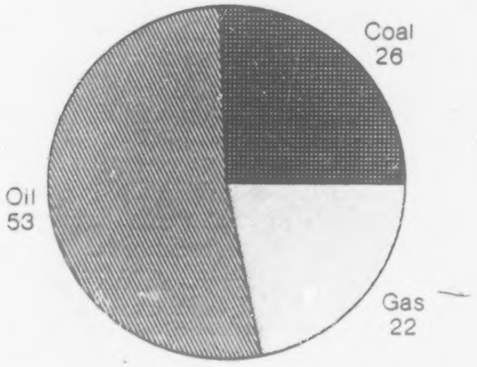


CALIFORNIA CARBON DIOXIDE EMISSIONS BY SECTOR
Percent



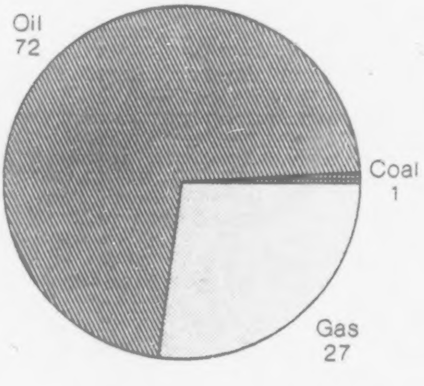
MACHADO AND PILTZ, 1988

U.S. CARBON DIOXIDE EMISSIONS BY FUEL
Percent



Machado and Piltz, 1988

CALIFORNIA CARBON DIOXIDE EMISSIONS BY FUEL
Percent



Some additional CO2 is produced by out-of-state coal plants

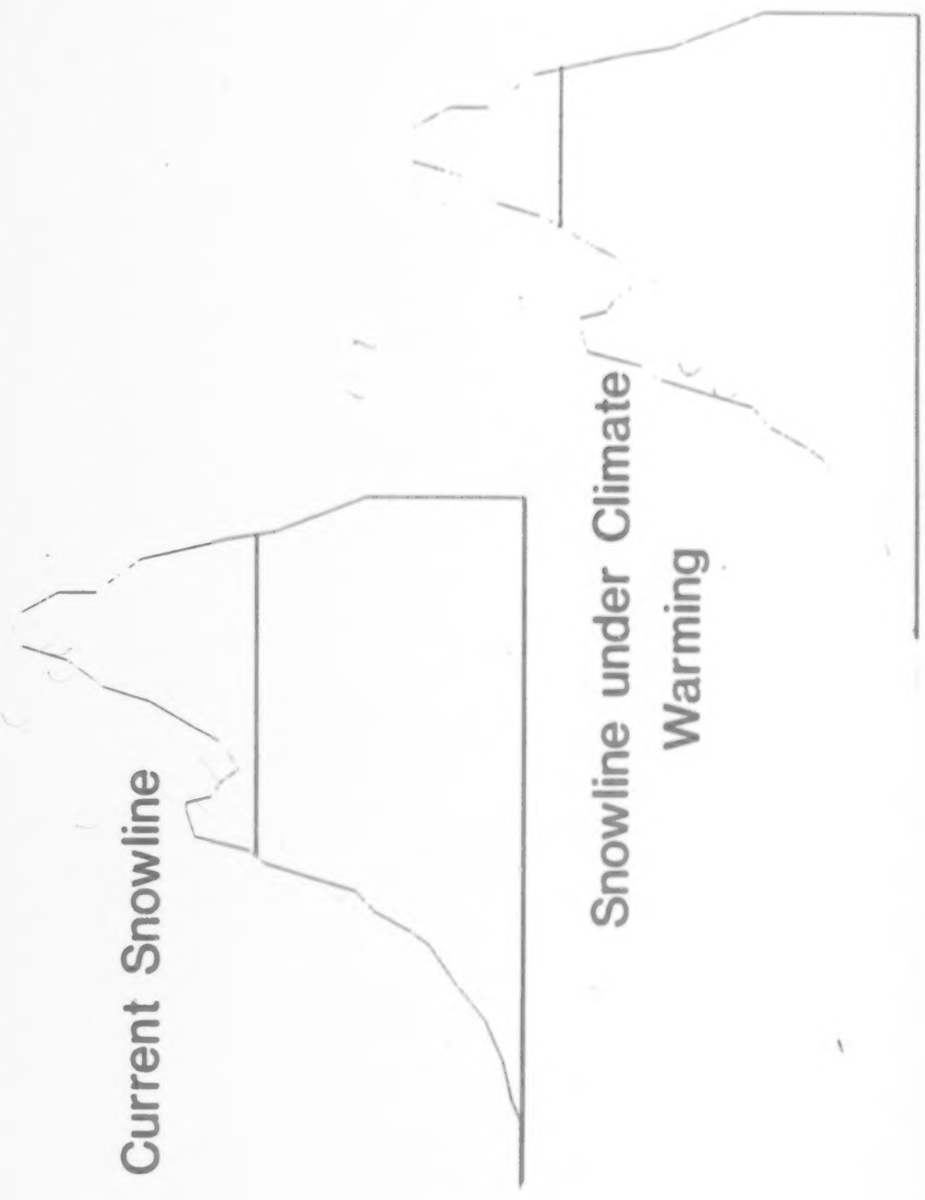
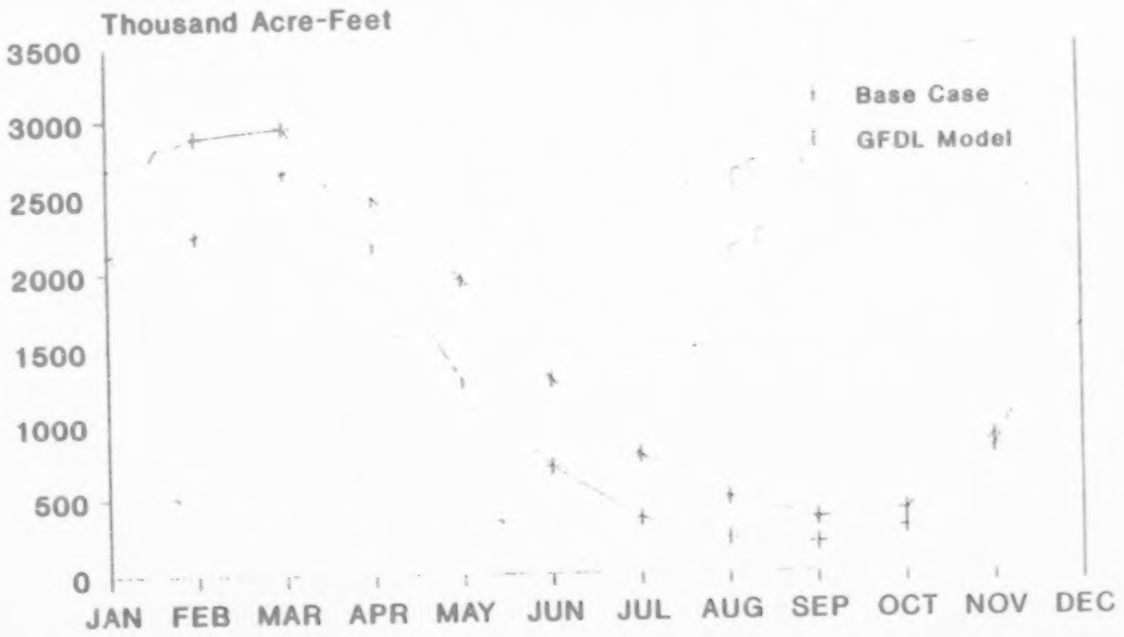


FIGURE 3

CLIMATE CHANGE AND RUNOFF
SACRAMENTO BASIN RUNOFF CHANGES USING GCM TEMPERATURE ESTIMATES

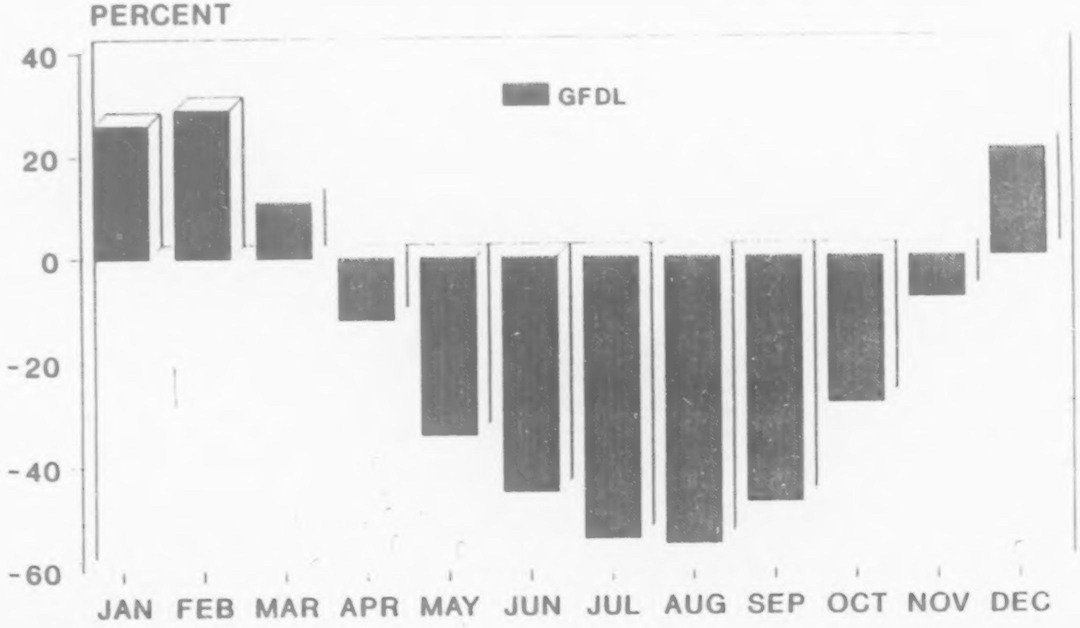


(source: Gleick 1987)

FIGURE 4A

CLIMATE CHANGE AND RUNOFF

SACRAMENTO BASIN CHANGES DUE TO GCM TEMPERATURE INCREASES



(source: Gleick 1987)

FIGURE 4B

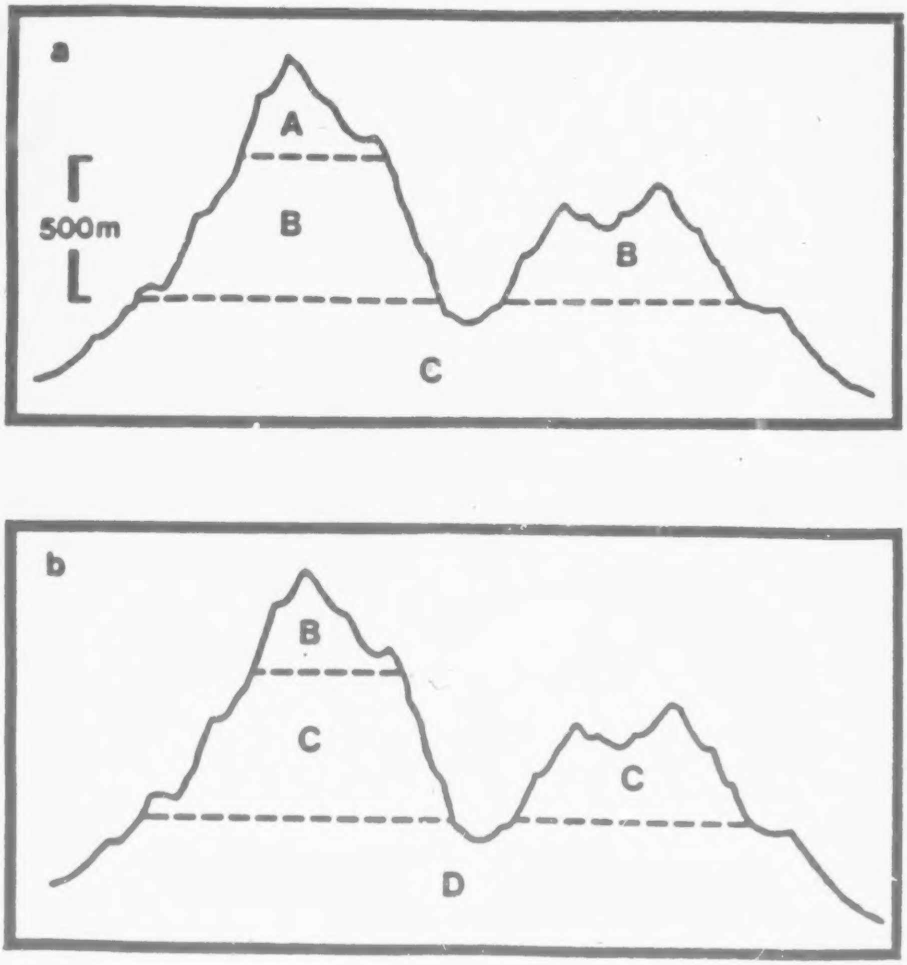
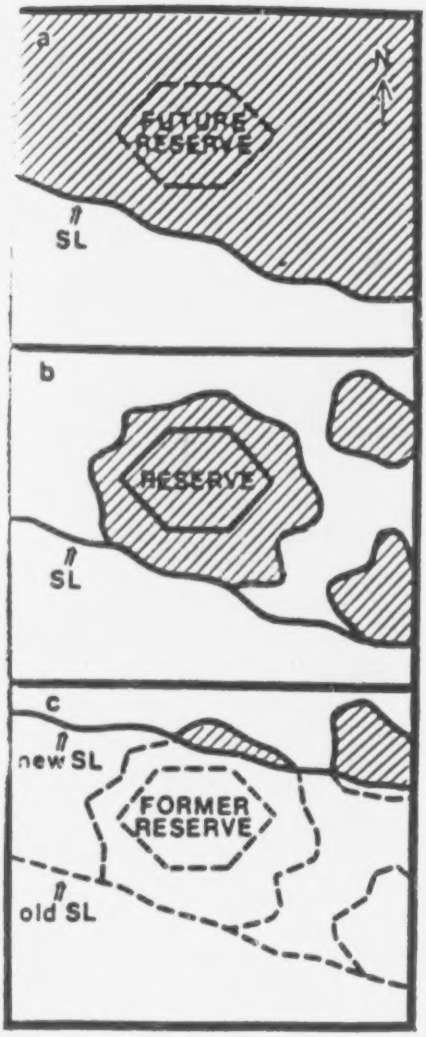


FIGURE 5


a
N
FUTURE RESERVE
SL
b
RESERVE
SL
c
new SL
FORMER RESERVE
old SL

··GURE 6

STATEMENT OF DR. JOHN A. DRACUP, PROFESSOR, SCHOOL OF ENGINEERING AND APPLIED SCIENCES, CIVIL ENGINEERING DEPARTMENT, UNIVERSITY OF CALIFORNIA, LOS ANGELES, CA

Dr. DRACUP. Thank you, Senator Wirth. It is a pleasure to be here and thank you, ladies and gentlemen for coming. I would like to begin my presentation by a quote by the auto pioneer, Henry Ford, who once said, "The future ain't what it used to be". And I think those remarks are as appropriate today as they were when he made them decades ago. I am a professor in the Civil Engineering Department at UCLA and I teach graduate and under-graduate courses in water resources and hydrology. And my testimony will focus on that area and the impact of global climatic change on the water resources of California which we have heard a little bit about already.

Steve is going to run my slides and the first one, one of the problems of California is the distribution of water and people. This line I have drawn here between San Francisco and Sacramento on this map is not to split the state into northern California and southern California, but to indicate that 75 percent of the water is generated as natural runoff north of this line, but 85 percent of the people are south of this line. And we have 28 million people in California, 14 million in southern California and it is one of the largest areas of water purveyors in the United States.

The other problem in water resources in California is in the way water is used. This is the net use of water and we can see that the bulk of it goes for irrigation, particularly in the San Joaquin Valley of California which is the largest valley in the United States in its production of agricultural resources. Urban only constitutes 16 percent and the other uses are rather minor. Because of this, we have over the years, built massive systems to move water from the northern direction into the south. The first of this was built in 1910, when the City of Los Angeles built the famous Orange Valley system with gravity flow all the way south and it is, as few people realized, only owned and operated for the City of Los Angeles, which is one of 83 cities in the County of Los Angeles.

The next system that was built was the Central Valley project in the San Joaquin Valley which was built by the U.S. Bureau of Reclamation. It is owned and operated by that agency. It was built in the 1930's mainly for irrigation on the east side of the San Joaquin. In the late 1930's, the Metropolitan Water District of Southern California, a wholesaler, built the Colorado River Aqueduct which has it's linchpin at Hoover Dam and it brings water into the coastal areas of southern California, supplying water from Ventura County through San Diego County. If you live in Santa Monica as I do, your water comes from that aqueduct.

The last major system built was completed in 1972. This is owned and operated by the State of California, Department of Water Resources, and it brings water along the west side of the San Joaquin Valley as a 2,000 foot pumping lift over the Tehachapi's into southern California. So, due to this disparity in population and water, we have built these large systems. In the face of climatic change, what is important to realize that these systems, first of all, have finite capacity, both the canals that convey the water and the dams themselves, and also they were planned and designed for current stationary climate conditions, not for the uncertain climate that we face in the future.

As Dr. Gleick has already mentioned, we know intuitively that there will be a rise in the freezing level in the Sierra Nevada Mountains. A recent study by the California Department of Water Resources indicates that a three degree warming in temperatures will raise the snow level fifteen hundred feet. This is bad news for skiiers, but also this has very profound impact on the water resources. Assuming the precipitation remains the same, we obviously are going to have more of the precipitation falling as rain in winter. Therefore, as Dr. Gleick has mentioned, we are going to have higher winter flooding, more erosion during the winter time periods and we are going to have less runoff during the important April to July time period, where it is needed for irrigation.

Again, the recent study of the Department of Water Resources indicates that there will be a 75 percent loss of snow in the critical north Sacramento Basin and a 33 percent loss of snow in the San Joaquin area. Again, this is for a three degree centigrade of warming.

Now, this does not translate directly into runoff because, as I mentioned, some of the precipitation will fall as rain and will run off during the winter. But, essentially, in this critical April to July period, due to this three degree warming, we will have a reduction of 43 percent in the Sacramento River area and a reduction of 33 percent in the San Jaoquin area. So, in the critical California Delta which is the Sacramento/San Joaquin Delta, which again is linchpinned for California water resources, we are going to have this decrease in flow coming in to a time period where we need it for irrigation and water supply and an increase at the same time in salinity that is coming in from the San Francisco Bay estuary.

We are also, as mentioned, going to have an increase in drought frequency and severity. But also, most importantly, we are going to have a reduction in hydro-power. I could not be a professor without putting up an equation. So, we have hydro-power is directly proportional to the flow rate and the head through the turbines. So, where we are having a reduction not only in the flow rate due to these reduced flows that are available and also from the reduced heads.

Now, you might argue, if we have a reservoir, does it matter? If we have the same precipitation, what difference does it make if it runs off in the wintertime or in the spring time? The answer is that the reservoirs are designed for a timing of runoff. They are designed to store the winter snow pack as it runs off in the spring at the same time that water is being released for irrigation at that time period. So, it is not a long term year-round storage, but it is a flow in and out as the demand downstream demands. Therefore, we will end up finding that our reservoirs have reduced yield and we will need larger reservoirs and larger canals.

We have also heard talk of the rising sea level. And this is a problem for coastal aquifers. Twenty-five percent of the water supply in southern California comes from ground water. And that is blended with the imported water from northern California and from the Orange Valley. As you can see then, if we have this rise in the ocean, the gradients to the ocean will be changed. Water will be moved into the aquifers. Once the salinity gets in there, it is very difficult to get out and we will have a reduced pumping available from these aquifers.

So, as one resource planner, it is essentially, "What can we do"? Both Dr. Gleick and myself testified before the Association of California Water Agencies last Wednesday in their annual meeting in southern California. Needless to say, they were not happy to hear our words. They have enough problems in their current planning and design and management of water resources without dealing with this future uncertainty. But those of us in the universities and consulting and engineering firms have to move into this planning under uncertainty that we do not have currently.

We will have to have an increased conjunctive usage of ground water and surface water basins. The Metropolitan Water District of Southern California is active in that. What I mean by this is, trying to fill our ground water basins now with surplus water in order that they will be available in the future and in this face of global warming. Increased water conservation, which we hear a lot about and the economists for years have been talking about water is cheap. Here in Santa Monica, I pay a dollar fifteen per thousand gallons for water. Many people do not even know what they pay for water. Water is cheap but there is not a mayor in this country that wants to hear that the prices of water should be raised.

But this certainly is a mechanism for water conservation as are the other useful practices that we can make of water, both in our homes and in agriculture. Also, we need to include small innovations measures in our current planning and design of water resource systems. For example, the withdrawal of water supplies in estuaries can be moved further up stream away from the salinity. Thermal withdrawal levels need to be installed in reservoirs. There is a number of things I believe can be done that are not necessarily that expensive at that time period.

Finally, we need to include economic incentives to water agencies, local, state, water agencies, to include climate warming in their planning and design procedures. These might be government subsidies and incentives to include that in the planning procedure. My full testimony has been prepared and will be included in the record, but at this time, I'll conclude my remarks. Thank you, gentlemen.

[The prepared statement of Dr. Dracup follows:]

Committee on Energy and Natural Resources
U.S. Senate
Washington, D.C. 20515

Oversight Hearing on Global Climate Change
Lincoln Middle School
Santa Monica, CA 90403

May 20, 1989

Effects of Global Warming on the Water Resource Systems in California

by

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90024-1593

Introduction

I would like to begin my presentation with a quote by the auto pioneer Henry Ford who said: "The future ain't what it used to be". Certainly his remark made decades ago is as appropriate now as it was then.

My testimony will focus on the potential impact of global climatic warming on the extensive water resources of California. The water resource problems of California are excerbated by the geographic distribution of water and people in the State. If we draw a line across the state from San Francisco to Sacramento to Reno, Nevada, we find that most of California's water supply originates north of that line while three-fourths of the water use is south of that line. Furthermore, approximately 87% of the water used in California is withdrawn for agricultural irrigation. The remaining 15% is used for municipal and urban purposes. Therefore, vast water conveyance systems have been built to move the water from the wet north to the dry south. While these systems are large and complex they are finite in their capacity and in their ability to store and move water.

Focusing on the effect of climatic change on water resource development in California I will cover three major points:

1. The identification of two highly likely future events which will significantly affect water resource development.

2. The identification of a specific financial concern.

3. The identification of potential mitigating measures.

Although it may be too early in the course of scientific research to precisely determine the effect of global climatic warming on large scale water resource development, two events can be identified as being highly likely to occur. These events would have a dramatic impact on water resource systems in California.

Rising Snow Levels

First of all, it is highly probable that an increase in global atmospheric temperatures of 2 to 5°C will cause a rise in the snow line or freezing elevation on the surface of the earth. This fact alone will have a profound impact on the volume and water content of the snow stored in the mountain of the Western states. Using a global warming of 3°C, the California Department of Water Resources has predicted a 1500 feet (460 meter) rise in the freezing level elevation for the Sierra Nevada Mountains of California (Roos, 1989). This change translates into a 54% reduction in the total Sierra Nevada snowpack. However, the reduction in the vital Sacramento River Basin snowpack in the wetter northern part of the State is predicted to be 75%.

Changing Runoff Patterns

The loss of snow storage will affect virtually every aspect of the U.S. Western water industry. Water resource planning and development relies heavily on the accumulation of snow during the winter storm months of December through March, and a subsequent melting and release of water during the spring months of April through June. Assuming no changes in total precipitation, the result of a climatic warming will be an increase in streamflow runoff during the normal snow storage winter months. That is, the precipitation will fall as rain instead of snow during the predicted warmer winter months. There will be a corresponding decrease in streamflow during the normal snowmelt runoff months of April to July. The California Department of Water Resources is predicting a 34% reduction in the April to July runoff from the Sierra Nevada Mountains due to a 3°C climate warming (Roos, 1989). This change in the monthly timing of available streamflow will profoundly effect several components of multi-purpose water resource development.

Reservoir yields for water supply and hydropower will be reduced. One AAAS (Dracup and Kendall, 1989) study indicates that up to 50% reduction in reservoir yields will occur. This is due to the change in the relative timing of streamflow runoff as compared to the timing of downstream water supply demands. During the fall months, water from reservoirs will have to be prematurely released to contain the increased winter runoff. Otherwise significant winter month flooding will occur.

Hydropower production also will be reduced. The peak power demands in California occur during the summer air conditioning season. Reduced summer reservoir storages and streamflow runoff will in turn reduce hydropower production during the time period when it is needed most.

The changing runoff pattern and reduced streamflow will increase the severity and frequency of hydrologic drought. An AAAS study indicated that a 10% change in streamflow availability translated into a 40% increase in hydrologic drought severity (Dracup and Kendall, 1989). Similarly, winter flooding will dramatically increase in both frequency and severity.

Therefore, an analysis of reservoir storage requirements during climatic change scenarios indicates that larger reservoirs will be needed to store the winter runoff and to meet current water needs. However, larger reservoirs may not be economically, environmentally, socially, and politically feasible.

Sea Water Intrusion

The second highly likely climatic warming event, which will dramatically effect water resources in California, is the predicted rise in sea level. Current sea level increase predictions range from 0.4 feet (0.13 meters) to 3.3 feet (1 meter) sometime during the next century. Saline intrusion into the Sacramento-San Joaquin Delta will dramatically increase. The Delta is the linchpin for all of California's southward pumping and movement of fresh water. The combination of decreased late spring streamflow runoff into the Delta, plus increased salinity from the Pacific Ocean and San Francisco Bay, could bring back the requirement for a Peripheral Canal around the Delta. This concept was rejected by California voters in a 1982 referendum.

Sea level rise also will cause increased salinity intrusion into coastal aquifers. The net result will be loss of fresh water supplies due to reduced inland pumping requirements.

In summary, change in the availability of snowmelt runoff will significantly affect the timing and availability of water supplies for agriculture, urban areas, and industries. These entities will have to develop new sources of water, expand existing sources, or shift to a heavier reliance on ground water supplies. However, the development of new sources of water and even the expansion of existing sources may be difficult, if not impossible, to achieve in today's social and environmental climate.

Economic Aspects of Climatic Change

The economic feasibility of large scale water resource projects requires that the present value of benefits be greater than the present value of costs over the expected life of the project, usually 50 to 100 years. This concept, although easily and simply stated, is often difficult to determine in practice. Current benefit/cost studies of existing water resource systems have been predicated on the assumption that the climate will be stationary, at least during the economic life of the project.

Climatic change could dramatically upset this delicate economic balance of future benefits versus current cost. The future benefits will become more uncertain when compared with the greater certainty of the current costs. Therefore, under conditions of climatic change, traditional benefit-cost analysis could become very unreliable as a tool in determining the economic feasibility of future water resource projects.

Financial Feasibility Under Climatic Change

The financial feasibility of water resource projects involves the crucial question of who will pay for the initial project development. These initial costs primarily involve the millions of dollars required for the constructing of the facilities. Water resource projects are invariably paid for through the issue and sale of revenue bonds, which are purchased by various financial markets and institutions. The ease at which these bonds are marketed and their value in the financial community is an important function of their competitive rating. The rating of a bond is a direct function of its risk to an investor. The higher the bond ratings the more attractive they are to investors and the more negotiable they are in the financial community.

Obviously, climatic change and the associated uncertainties which will come with it will increase the risk of investment in water resource projects. Therefore, water resource revenue bonds may be less attractive to investors and more difficult to sell. Water resource projects may become more difficult to finance and to build.

Environmental and Institutional Feasibility Under Climatic Change

Existing physical structures (e.g. dams and aqueducts) have been designed to deliver water under present climatic conditions. Similarly, existing water resource institutions, rules and practices have been formulated under present climatic conditions. These institutions have been fashioned to respond to current concerns of equity, environmental quality and efficiency.

Advance knowledge of global climate change is most useful when it provides an opportunity for rational human response. A number of changes are occurring in water policies and institutions that will affect future human responsiveness to climate change. These include the declining influence of U.S. national water institutions, the increasing role but limited perspective of the states, the increasing role of water markets, the continuing ignorance of scientific hydrology, and an insensitivity to environmental and third party effects. An objective assessment of the water policy and institutional problems that are likely to be encountered during climate change needs to be assessed.

The topic of how U.S. water resource policies and institutions will be subjected to stress due to climatic change is important and needs to be addressed. Estimates need to be made of the flexibility and resilience of the policy, or institution, under climatic stress where change may involve sacrifices of efficiency, equity or environmental quality. The future vulnerability of these values as a result of institutional adaptation needs to be determined.

Changes in Water Resource Management Practices

Climatic change will not allow a continuation of business as usual for the U.S. water industry, particularly in the Western states. Alternatives available to water resource planners and managers will not include the option of doing nothing. Increased winter streamflow will force water resource managers to either spill the water from inadequately sized surface water reservoirs and let it flow to the ocean or to effectively manage the water and store it in ground water reservoirs. The quality of the water in the ground water aquifers will become an even more critical issue.

Drastic price increases may occur. In the City of Santa Monica, where I live, the price for the urban water supply is $1.15 per 1000 gallons. The source of this water is local ground water plus supplies originating as far away as the Rocky Mountains to the east and the Sierra Nevada Mountains to the north. Agricultural supplies are similarly inexpensively priced. Most urban residents actually do not know what they pay for water. Furthermore, their water charges are usually a minor percentage of their monthly utility bill.

I have often asked people who have recently migrated to Southern California, a semi-arid region of our country, a question which I consider to be legitimate: "Before you moved to Southern California did you call any local water agency to determine whether or not adequate water supplies would be available to you once you arrived". Most individuals either smile at this seemingly naive question or stare back in disbelief. Americans are mobile and wherever they move to they expect to find the electricity, water and telephones instantaneously available to meet their immediate needs.

Under future climatic change, the way we currently view water and our expectations concerning water from a legal, economic, financial, social, and even political standpoint may drastically have to change.

Potential Mitigation Measures

The loss of available storage space in surface water reservoirs should lead to an increased dependence and usage of the water stored in ground water basins. In Southern California, 45 percent of the municipal, industrial, and agricultural water supply is currently pumped from ground water reservoirs. Therefore, the conjunctive use of surface water and ground water reservoirs will become an increasingly important planning and operational procedure used to alleviate a developing critical shortage of surface water reservoir storage space. The conjunctive use of ground water basins will involve the artificial recharge and storage of surplus surface water supplies which will be available during the winter months for subsequent pumpage during the high demand summer irrigation season. Studies by the California Department of Water Resources indicate that surplus waters are currently available at the Sacramento - San Joaquin Delta during January through April even during below normal flow years.

The California Department of Water Resources has suggested that small scale, inexpensive features may be added to water resource projects during the initial construction phase which will be beneficial in a warmer climate scenario (Roos, 1989). Adding temperature control works on new dams and moving water supply intakes further upstream in saline estuaries are examples. The water resource manager must keep abreast of potential climate changes and plan for greater uncertainties in their future plans and designs.

Conclusions

The consequences of global warming on water resource systems throughout the United States will be significant, widespread, and expensive to mitigate. The lead time required for the planning, design, and construction of large scale water resource systems can span ten to twenty years. Therefore, it is imperative and urgent that we begin now by giving federal, state, and local water development agencies economic incentives for including in their current planning procedures the impact of global warming. These incentives could include government subsidies.

Global climatic change has the potential to impact existing and future large scale water resource projects in the Western U.S. in a severe, sustained, and permanent manner. Not only the ability of these water resource projects to function in their designed engineering and technical capability could be threatened, but also their economic, financial, social, legal, and environmental feasibility may be in jeopardy.

Summary

In summary, the two highly likely future events which will significantly affect water resource development in California are:

1. A significant decrease in winter snow storage in the mountains of the Western U.S. and a dramatic change in winter and late spring runoff patterns. This will lead to an inadequate amount of existing water reservoir storage space.

2. Sea water level rises which will bring salinity into the Delta and into coastal aquifers.

The specific financial concern is the potential inability of state and local water agencies to sell general revenue bonds for large scale water resource projects due to their increased risks.

The four mitigating measures proposed are:

1. An increase development and reliance on the conjunctive use of ground water basins.

2. Conservation of water via the increased pricing of agricultural industrial and urban supplies.

3. An inclusion of inexpensive, small scale, innovative measures in the planning and design of new water resource projects which are attuned to climatic warming.

4. Economic incentives by the federal government to induce state and local water agencies to include the potential for climatic change into their current water resource planning procedures.

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Senator **Wirth**. Well, Dr. Dracup, thank you very much for that excellent and also very sobering examination of the water resource in California. Let me, if I might, start by asking a question that I would ask all three of you to address yourself to. As we look at the issue of global warming the suggestion is made over and over again that this is going to make us think quite differently about the world around us. It makes us think quite differently about fossil fuels, about man's impact on the planet in that fashion quite differently, about the necessity of conservation, quite differently about various economic incentives that you were discussing particularly right at the end, Dr. Dracup. There's a whole variety of ways of thinking differently or thinking smarter.

One of the groups that has been most involved in all of this have been various environment and conservation groups, who have been pushing very hard on the issues of global warming and on the fact that we again have to re-examine and think this through differently. People on the other side say that it is imperative as well that environmental groups are going to have to start thinking perhaps differently than they have in the past. Two issues have probably catalyzed environmental groups as much as anything else. One of those has been resistance to water storage programs which have been in many cases environmentally destructive and the pattern of water storage has, therefore, changed very significantly in the west.

Another issue that has organized and catalyzed environmental groups has been the nuclear issue, the opposition to nuclear power. And it would seen to me that as we enter the day and age of global warming that perhaps we are going to have to rethink those two issues as well. If we look at fossil fuels and the carbon dioxide impact, does that suggest that we are going to have to rethink nuclear power as we look at the changing patterns of snowfall and snow pack and distribution of water, does that mean that we are going to have to rethink the way in which we capture water? Are the nuclear and dam sites going to have to be rethought? Let me ask—any one of you might want to respond to those modest, easy, substantive political issues.

Dr. **Dracup**. Well, Senator, I would like to address the water storage question. As we all know that large water resource structures, such as dams and their associated reservoirs inundate large areas behind them, for example, in the Two Forest Dam in Colorado, that after spending millions and millions of dollars of environmental impact studies and other studies, the dam was deemed unacceptable by the public, socially unacceptable and it is my understanding it is not being built. I think that an alternative to going to new dams is to look at the raising of existing dams.

There was some talk some years ago of raising Shasta Dam. Now, there is a dam that already exists. It is widely used for recreation and therefore, I think that looking at existing structures and looking at the feasibility of raising them 10, 20 feet, you get significant amounts of storage and it is an existing area where people are used to having that type of structure there.

Dr. **Gleick**. I would like to talk on both of the issues, water storage first. Certainly we should reconsider water storage systems. We always do anyway. There are always a few more sites left that people would like to perhaps build a dam on. But, the best sites for reservoirs, certainly in California but I think most—this is true in most of the United States are gone. We have built dams on the best sites. We have protected some of the few remaining sites for their environmental values. I do think we will reconsider the issue of water storage to some extent due to the issues raised by climate change, but it is always cheaper first to look at changes in the way we manage and distribute water resources, the way we plan our water resources.

For example, this change in the seasonality of runoff in northern California due to the snow melt changes, we do not yet know whether the existing reservoir system can handle that by simply changing the way we think about flood management, by thinking about changing our timing of filling and releasing water with the existing reservoirs. And it would be very inexpensive for the Department of Water Resources and the Federal agencies that run some of those reservoirs to look at that. And, of course, I would argue that is the first thing we need to do. If, in the end, it looks like we are faced with higher flood risks, perhaps we should think about changing the way we handle flood management and building flood plants. That is also, to a great extent, cheaper than building a new reservoir. Now, that is all I want to say about water storage.

About nuclear, yes, we need to rethink the nuclear option if only for the fact that nuclear power does not produce carbon dioxide during its operation as does fossil fuels. On the other hand, when we look again at the problems that nuclear power has always had, they still have those problems. It is still an expensive resource. There is still safety concerns. There is still public opposition. There is still no satisfactory waste disposal site. The idea of developing a so-called inherently safe reactor is a great idea and if we can develop one that is commercially acceptable, inexpensive enough to build, then I think the nuclear option will look a lot better. But until we do develop such a reactor and there is no such reactor today, I think there are faster and cheaper things that we can do today rather than waiting until a new nuclear system perhaps will be available and conservation and renewable resources have been mentioned.

And I would certainly encourage research on those topics. But I think waiting for them might be a mistake.

Dr. **Schneider**. The issue of global warming as you correctly pointed out, Senator Wirth, challenges all ideology. And just by way of prefatory remark, ideology is inflexible. And if there is any message inherent in the high probability of rapid change whose exact details are not certain, it is that we need to have flexibility. So, the single best adaptive mechanism we can have is to try to develop as many flexible management options as we can as well as technologies.

Clearly, for nuclear power, the issue is not, as it has become an ideology, opposition to the end word. It is cost and safety issues. And if, indeed, light water reactors which suffer from the, in my view, any retractable difficulty that operator error or unforeseen catastrophe will lead to a melt down, at least to what the public has now believed to be unacceptable safety risks. But there are other cycles, as Dr. Gleick mentioned as you are aware of, that do not inherently melt down.

There is a line attributed to physicist Edward Taylor when he said that, "For every fool-proof system there is always a fool of sufficient magnitude to overcome it". And that is the problem with light water reactors. But not all nuclear power systems need be light water reactors. And it would certainly seem to me that part of flexible management in the future is to consider a whole range of options. How do we get the cost and safety of photovoltaics. The safety issue is not very serious there, but cost certainly is. There is transmission line questions and storage.

So, to make the future more flexible we need national security investments as a number of Senators mentioned, in providing the information which would tell us what the cost and safety are of these alternatives at a much more accelerated rate than if the market system is left to its own devices. After all, all of us buy insurance without cost benefit options. We buy military without doing economic calculations because we believe in preserving our freedom. Well, preserving our environmental freedom is part of that and there will have to be ideological concessions made on all sides if the future is to have that kind of flexibility.

Fortunately, in the short run, we have a great deal of flexibility which comes out of the relative inefficiency of our own use of energy now. And because of that inefficiency of which many of us are aware and we decry, that is an opportunity, because it is an opportunity to make very cost effective and immediate investments. Nevertheless, sometime down that line, we need primary energy and the extent to which it is nuclear, I do not know. But I certainly think it would be fool-hearty not to invest in finding out what the actual safety and costs would be of new nuclear processes as well as photovoltaics and natural gas conversion and a whole variety of things. Once again, the key to being able to adapt to global warming less painfully is flexibility.

Senator WIRTH. To summarize, if I might, and then we will move to Senator Cranston. To summarize, it seems to me that in the short run in both the areas of power and water, it is clear that the immediate option is conservation and efficiency. And we have a lot of room in both areas in our society to save a great deal and that is going to help in the transition to what I think we all believe is going to be a warmer world. The question that we also have to face is, what do we do for the twenty-first century. And in preparing for that, we have to begin now. We have to begin to make the investments now and research and development at the Federal level. I think that all of us here would argue that we have to be much more active than we have been, particularly over the last eight years.

On the nuclear side, it becomes pretty clear that there is a lot of long-range research to be done in the area of nuclear and controversial as that may be, it seems to me a prudent individual would say, "We have to give it a try. Maybe it will not work, but I am not prepared to say that I can pre-judge that in May of 1989, whether it will or it will not".

It seems to me in the area of water, as you were suggesting Dr. Dracup, perhaps we ought to be beginning now also to look at what might be different weather patterns and different snow pack patterns and particularly in the west, as both your slides and Dr. Gleick's slides suggested. We're going to have a very different snow pack, very different natural storage conditions. And we ought to be looking, perhaps putting some more money into this. Is that what is necessary to be looking at long-term research? Should we be telling the Bureau of Reclamation that this is a variable as your last slide suggested, that they must be focusing more of their research on what options we may have for the twenty-first century. I guess that's the final question. Is that currently going on, or do we need a more targeted effort in the area of water?

Dr. **Dracup**. Well, as an academic, I will never turn down money.

Senator **Wirth**. Well, is it already going on?

Dr. **Dracup**. To my knowledge, I am not aware of any stage in the Bureau of Reclamation. I know that the California State Department of Water Resources and certainly Environmental Protection Agency, yes.

Dr. **Gleick**. Actually, the Pacific Institute is doing a study with the EPA and the Bureau of Reclamation right now on the implications of climate change for the Colorado River. We are looking at changes in runoff patterns, what that would mean on delivery to users, salinity levels, hydro-power generation and the Bureau has agreed to participate in that study as a planning tool really, to begin to think about how they should think about these kinds of problems. But it is just beginning. There is a tremendous amount more attention by Federal and State and local agencies into these issues is needed.

Senator **Wirth**. Well, certainly we would appreciate any comments that any of the three of you might have on what kind of a research and development regime or approach we ought to be putting together at the Federal level would be encouraging, as to what might we do if this long-term water issue is going to escalate is a problem as the two of you were suggesting this morning. Senator Cranston?

Senator **Cranston**. I would like first to thank my colleague for spending so much time on this issue and the California aspects. I know it has national and world aspects, but you are very good to spend this time on the California concerns that we have. And they are examples, obviously, of what we face all over the world and all over the country.

I would like to ask any one of you about one statement that appeared in the Los Angeles Times awhile back. It was various projections of the increase that will result from greenhouse warming in ocean rising range from 10 feet to 25 feet by the end of the next century. That is on the far side, but is that a possibility in your opinion?

Dr. **Schneider**. In science, we never prove anything by proving it. We prove it by trying to disprove it. So, one can never make an absolute statement about anything, but it is—that particular range, the 10 feet to 25 feet came from work that was done about ten years ago under the assumption that a part of the Arctic ice sheet, so-called west Arctic ice sheet, could be broken up and rapidly surge into the ocean at a time—by rapidly, I mean at a time frame of a hundred years. Now, most glacialogical studies suggest that that is many hundreds to perhaps a thousand years. So, while those sea level rise numbers are not outlandish for many hundred years in the future, they would be an extremely low probability in the time frame of say a hundred years.

That was the good news. The bad news is we have discovered since the last ten years that there is a much higher likelihood of a sea level rise of several feet due simply to the warming of the oceans associated with global warming. Like any thermometer, which is a fluid in a tube, if you heat the fluid, it rises up the walls of the tube. The fluid expands and the walls constrain it, so it rises. Similarly, the fluid is the ocean and the tube is the continental shelf. But one point we need to keep in mind about a sea level rise of quote "only" unquote, a few feet, it is not so much that the few feet means that we get our toes wet. What it means is, it is a higher base line against which storm surges, which is the periodic traveling of cyclones or hurricanes occur, those can lead to 10 or 15 foot high temporary—they may only last a few hours, but the damage is done—surges.

Now, if you increase the level by several feet, then what that does is it substantially increases the probability of crossing some fixed threshold like 10 feet. And that is what does damage and that is what affects our permissible land use. So, if you are going to have a ten foot storm surge every hundred years, statistically from a hurricane, say, you raise the sea level a few feet, all of a sudden it becomes every 50 years or every 30 years. It completely changes the concept of that land use.

So, it is not inappropriate for us to think about 10 foot sea level rises even though they are going to occur infrequently. It is that the frequency increases and in that sense we still have to worry about it.

Senator **Gore**. Could I interject a brief point? And simultaneously the same effect is predicted to cause more frequent and more severe storm systems of exactly that kind.

Dr. **Schneider**. Certainly, the more intense hurricanes—there is a very good plausibility argument and the Senator is right. Simply, we know that hurricanes, for example, will occur in the warm season, in the summer and in the fall simply because their energy source is hot water. So, if the water is hotter and the thickness of the so-called mixed layer is unchanged, then it is a very good bet that we will have more intense storms.

Senator **Cranston**. Steve, last year we had raging forest fires throughout much of the west. What do we have to anticipate in terms of developments on that part?

Dr. **Schneider**. It is a complicated issue. I had a U.S. Fire Service sponsored workshop on exactly that subject last September. The Forest Service was very proud that we had scheduled that back in the winter so they did not look like they were faddish. But what we concluded is there were multiple factors associated with forest fires. It takes really three things. You have to have the fuel level there. That means you have to have a build-up of tree debris and so forth. And the longer the distance between fires, the higher the fuel level that you have built up.

The second thing you need is a fairly intense dry spell. It might be as little as weeks. It depends upon how much humidity there is, or it could be as much as months. And the more intense the dryness, and the third thing is you need a match, whether it is from us or from nature. So, all three of those aspects could be effected by global warming. You could change the matches, if you will, by changing the frequency of lightning. We have no way to know at this moment in either direction how that would work.

As far as changing the intensity of heat, certainly in a Mediterranean-like climate such as California which is already is summer dry and winter wet, we do not foresee at least let us say in the time frame of fifty years, changing the climate so radically that you would lose that basic structure. So, cranking up the heat makes a very good certainly circumstantial case that you would increase the likelihood of having those heat waves that pre-condition into fires. And then ultimately what happens to the tinder, how much material you have will depend, in part, upon how rapidly the climate changes. As I have said in my oral remarks, it could be that during the period of rapid climate change, forests now accustomed to present climates could die.

Yes, they would be replaced by other kinds of seeds. We might even have to plant them, but seeds that would be more adept there. But during the transition when those mature stands might not be adaptive anymore, you would have more tinder. And this could pose a substantial management problem as well as an ecological problem. It is one of the surprises that we are just beginning to think about if we perform this experiment of global warming on the planet.

Dr. **Gleick**. If I could just say one thing about that, there is a piece of research being done right now at UC Berkeley on the implications of climate change for forest fire frequency in California. And the work is not done yet but some preliminary results suggest that in addition to the problems that Dr. Schneider has mentioned, those fires that we currently have that do not get out of control may get out of control more frequently because of higher temperatures, because of changes in fuel loadings. Even if, as he says, the number of matches which in California tends to be almost entirely human, most forest fires are caused by human fires, that those forest fires will become more frequent and perhaps worse.

Senator **Cranston**. Peter, on drinking water for California, is the availability of that so severe from this that we might not be able to sustain the present population or projections of future population?

Dr. **Gleick**. Well, of course, we're already in a situation where the growing population and the expected increases in population in California threaten water supply, or perhaps to put it in a different way, there may simply not be enough water where and when we need it to match projections of future demand. The special problems posed by climate change include this change in the seasonality of water availability from northern California and we may not be able to store some of the water that we current store and ship to southern California for example.

We might not be able to store that, because it comes too quickly in the winter season. Another part of that problem is that it turns out that we use some of the water in the Sacramento River, for example, to flush salt water out of the delta, to keep the salt water at bay in the Bay, in San Francisco Bay. During dry years, that salt front pushes farther and farther up into the delta closer and closer to the delta pumping plants. This change in seasonality and perhaps a change in the frequency of dry years may mean that we have to devote more of that water to pushing that salt front away which means there would be less water available for southern California.

I think John has done some of the work in that area and perhaps he has some specific numbers. But the short answer is yes, I do think that climate change is going to make the water resource problem in California worse.

Dr. **Dracup**. Yes, Senator, I would like to add to that. One of the things that needs to be in the record, of course, it is a long lead time required for major water resource development. Looking at the planning, design and construction we are talking twenty to thirty years to bring these systems on line. Certainly, they are technically feasible. We could bring water from Alaska if we had to. We have that technology. It is available. But the lead time, of course, is tremendous. And the environmental, social, political feasibilities may not be there.

Senator **Cranston**. I would like to make just one comment. If you have any comments on this, I would be interested in them, but I have been very concerned about the nuclear war threat as another threat to human survival and to the security of our people and our country, and other threats like biological or chemical weapons, and now, obviously, global warming is a major threat. Because of my focus on nuclear concerns, I have paid a lot of attention to what goes on in the Soviet Union or try to understand that. I recently came across an interesting fact in regard to the thinking of one of their top scientists. He is a leading rocket expert, named Boris Rachenbach who was the first man to photograph the dark side of the moon. He worked to develop the space program. He is a member of the Academy of Sciences. He is a Renaissance man with a wide range of interests. And he has growing concern about the course of civilization and this world.

And over the years, he and colleagues there, like some Americans and others, have sent signals to other planets seeking a response from some other civilization. They never received replies, at least nobody has thus far and this particular man developed a theory about why no replies. He has calculated that the span of life of the technological civilization is about a 120 years once you begin an industrial revolution and begin to harness science or unharness science. And he believes that the absence of replies to his signals to other planets is due to that short life span, that is other technological civilizations may well have existed but they have self-destructed and right now, in this time frame, there is no other civilization to respond to our signals. Do you have any comment on that, the Russian viewpoint?

Dr. **Schneider**. Why are my colleagues looking at me? I might self-destruct. Let us hope that if there are other civilizations out there, they have a slightly different psychological structure than we do and are a bit more consciously rational about using their technologies in a way that does not ultimately limit their own growth.

Senator **Wirth**. Senator Gore?

Senator GORE. Well, thank you very much, Mr. Chairman. I found that very intriguing. I have thought about it in terms that are a little bit different, but I remember the old debate in the 1960's about appropriate technology, focusing for example on the question of whether or not a nuclear power plant might be inappropriate for a developing nation that does not have a utility grid already in place and looked at in those terms, it is fair to ask the question, when God gave human kind dominion over the earth, did he choose an appropriate technology? Are we capable of surviving and is our civilization capable of answering this threat? And it is really a very profound question.

We have to use technology, ironically, to solve the problems that technology has helped to create. And one of the things we will be hearing about in the next panel, if I am not mistaken is, how California has taken the lead with technologies like wind energy and solar power and other new developments that the entire country and the entire world will have to use. But we do also—you referred, Dr. Schneider, to our psychological structure. I think we are capable of changing the way we think about our relationship to this planet.

We have suddenly entered into a brand new relationship between the human species and the planet earth. All of a sudden we have billions more people. All of a sudden we have new technologies that magnify the impact of each one of those additional billions. And the real question, when you boil it down to its essence is whether or not we are capable of changing rapidly enough to stop these threats that our civilization is posing to the environment. Let me just ask a couple of brief questions and then go on to the Lieutenant Governor.

You talked about the projections, Dr. Schneider and you showed us the low projection, the mid-range projection and the upper range projection. Fifteen years ago, a scientist from California, Dr. Sherwood Roland, projected that by 1990 we would have a one percent loss in the stratospheric ozone layer because of chlorofluorocarbons and related chemicals. One of the reasons we did not respond to his projection is that a lot of people said, "Well, he may be wrong and it may not be nearly that bad".

Well, in fact, we now know he was wrong. Instead of a one percent loss by 1990, we have a four percent loss by 1989. And, the reason is there was what some scientists call a positive feedback loop, a magnifier effect that we could not anticipate because the natural system of the earth in a kind of balance or equilibrium. And when we interrupt important factors that make up that equilibrium, we better be prepared to—for the unexpected. And that is what has happened and is even now happening with the hole in the ozone layer over Antarctica.

Well, there are positive feedback loops or magnifiers that could produce some unwelcome surprises where global warming is concerned. Is that correct, Dr. Schneider, and what are some of those, just briefly?

Dr. SCHNEIDER. Yes, indeed it is correct. One of the potential ones that we worry a great deal about and do not know much about has to do with the amount of organic matter stored in the soil. We know that there is about as much carbon in the living matter of the trees as there is in the atmosphere. And there is maybe two or three times more carbon as dead organic matter in the soils. Well, that dead organic matter is eventually recycled back to CO_2, either initially through methane or directly to CO_2 by soil bacteria. Life is very much a part of our geophysical system. And the rate at which that organic matter is decomposed depends upon the temperature and the moisture and so forth.

And we know that these bacteria work much more rapidly and effectively where it is warmer. And anybody knows that for themselves, if they have ever accidentally unplugged their refrigerator and you open it up and you use your nose, you will find out that bacteria works much more rapidly when it is warm. So, there is the possibility that as we warm, we could substantially accelerate maybe by even a factor of two the CO_2.

Senator GORE. Well, let me just stop you right there. In other words, as the warming trend begins, it could unlock some more CO_2 that is presently stored in the biological system in the soil, correct?

Dr. SCHNEIDER. Yes, that is quite possible.

Senator GORE. And if that happened—and you say twice as much in the soils as in the atmosphere, fifty times as much in the oceans as in the atmosphere and the oceans both absorb and disorb CO_2 back and forth to the atmosphere.

Dr. SCHNEIDER. Correct.

Senator GORE. And those mechanisms may well be very sensitive to temperature change, correct?

Dr. SCHNEIDER. Correct.

Senator GORE. Now, one of the ways the oceans absorb CO_2 is by the tiniest plankton fixing carbon?

Dr. SCHNEIDER. Yes.

Senator GORE. Aren't there studies showing that increased ultraviolet radiation depressed the efficiency with which those plankton fixed carbon?

Dr. SCHNEIDER. Yes, and people are looking now in the southern oceans where we know that the Antarctic ozone hole has allowed substantial enhancement of ultra-violet radiation reaching the surface, and we are quite interested in seeing if we have a measurable effect in the plankton right now.

Senator GORE. Now, if one of the positive feedback loops started accelerating the trend, we might not see it for awhile, but one of the indications might be the beginnings of a more rapid rate of increase in the carbon dioxide concentrations, correct?

Dr. SCHNEIDER. That is a possibility, yes.

Senator GORE. Well, now in that graph that you showed us there, the average increase from one peak to another each year has been about 1.5 parts per million per year, correct?

Dr. SCHNEIDER. Yes, about.

Senator GORE. What has the rate been for the last eighteen months?

Dr. SCHNEIDER. Well, it has gone up in the last eighteen months. I have forgotten the exact figure.

Senator GORE. 2.5.

Dr. SCHNEIDER. Yeah, okay.

Senator GORE. Parts per million per year. There has been a surge in the rate with which CO_2 is rising. Well, there were some other questions that I would like to ask for the record. Just one final one here in the open session here. Doctor—who was it talked about the financial uncertainty? You, Dr. Dracup, was it not?

Dr. DRACUP. Yes, it is in my paper, yes, sir.

Senator GORE. Well, first of all, you made the point, Dr. Gleick, that the snow now holds the water and then releases it when it is needed in the spring. And if that stops, we are going to need new projects, perhaps. Dr. Dracup, just one final question. If we have to build a lot more projects, if we have to adapt in various ways, the financial markets will react of this uncertainty by making it more expensive to float bonds for such projects, correct?

Dr. DRACUP. Absolutely. That is right. With this uncertainty facing the investors and most large scale water resource projects are built with revenue bonds, and if they are a AAA rated, they have certain—a lot of people jump in and buy them and the interest rate can be lower. As the risk is included, the interest rate has to reflect the riskiness of the project. So, essentially, the financing of these projects could go up two or three percentage.

Senator GORE. Well, we will find——

Senator CRANSTON. What uncertainty and risk are you talking about?

Dr. DRACUP. If you look at the water resource projects, their economic feasibility is determined on a benefit cost ratio basis. So we have immediate cost and long-term benefits which have to be discounted into the present. So, what is going to be uncertain are these future benefits. And therefore, this increase in the uncertainty of future benefits will increase the financial uncertainty of these projects and make them riskier to investors.

Senator GORE. There is sometimes a tendency to think about adaptation in very simple terms. We have this state now and we are going to change to a new state and so, we have to adapt to the new state. One of the challenges with this is, we change to a new point of equilibrium and then we do not stop. We keep on changing. And the environmental patterns that emerge 20 years from now, unless we do something about this problem, will be almost impossible to adapt to, because as soon as we start adapting to them, they will change again. And so the whole business about adaptation, while we have to think about it because we have already locked in some of the change, this discussion really should reinforce our main conclusion and that is, we have to prevent most of this change from taking place, by changing the pattern of our civilization which is causing it. Thank you, Mr. Chairman.

Senator WIRTH. Thank you very much, Senator Gore. Governor McCarthy.

Mr. MCCARTHY. One or two brief questions. One of you referred to the option of filling our ground water systems. Was that you Doctor—all right, Dr. Dracup. And two of you indicated that you had spoken at—was it the Water—California Water District Association or the California Water Users?

Dr. DRACUP. The Association of California Water Agencies.

Mr. MCCARTHY. Which?

Dr. DRACUP. The Association of California Water Agencies.

Mr. McCarthy. Water Agencies. Did this subject come up there, our water usage?

Dr. Dracup. We made the presentation to them. And ground water was included as potential——

Mr. McCarthy. The reason I ask is that we have tried legislation several times in Sacramento. Of course, the most ferocious opponents of that legislation are the growers in the San Jacquin Valley and elsewhere in California. They simply view it as an intrusion by government into their total latitude to draw down from those underground water systems when they want.

So, what I am getting at is, I think they could be persuaded by a lot of the data that they are—is that the only appearance or contact you scientists have had with them or are there other contacts? Is there any approach——

Dr. Dracup. Well, a number of former students work for the Metropolitan Water District of southern California and other agencies around the state. The MWD is working with the Department of Water Resources in developing the Chino Basin in a ground water area where they recharge surplus water brought up by the State Water Project and use that in drought scenarios. A lot of things that we are doing now for drought scenarios, planning in that area can also be carried over to this global climatic warming scenario. And I would agree that the San Jacquin basin is a fertile area for ground water recharge but a major institutional problem.

Mr. McCarthy. One final other—did you want to make——

Dr. Gleick. Let me just add one quick thing. The American Association for the Advancement of Science, the AAAS, has just completed a study on climate change and water resources in the United States. The three of us are on the climate and water panel that is producing this book. And the principal message that has come out is really, that water users, water managers, hydrologists need to begin planning today for the kinds of changes that climatic change will bring to water resources. And we made a presentation in Sacramento to the Department of Water Resources. Bit by bit, people responsible for water management in California in particular, but in the United States are, I think getting the message and certainly need to get the message that they have to begin planning now for the changes that are coming in the future. That they can no longer assume that the climate of tomorrow is going to be like the climate of yesterday because it is not. And that the things that we have designed to handle our water resource systems for tomorrow may need to change in order to handle climatic changes. A lot more needs to be done, but it is an incremental process and I think things are being done.

Dr. Schneider. Two brief comments. One is with regard to those growers who point out that they didn't want government interference in ground water, I presume that they didn't want the government interference that spent the billions of dollars bringing the surface water project either.

And we all have to recognize—this is part of the ideology problem—that we take advantage of government service as well, and we need to rethink this measurement. And this is part of what I meant earlier by getting at the ideology, because we have to look at the whole system and from both directions.

The second part of that problem, I am reminded of this time that we did brief—all of us went up there to the Sacramento group, and I enjoyed that meeting, but I was a little bit surprised that many of the people responsible for water resources in this state rather than arguing about ways that could increase the flexibility were arguing about ways to deny that the problem was real. And they showed us pictures of temperature changes in California that were not going up and therefore, the global warming does not apply to California we were told. And I reminded them that if we had colored in the states in 1976—I had done this recently and the 1984 elections, I colored it in green on a map of the U.S. and all these states, the states won by the Democrats and in 1976 with President Carter won the election, about half the states were won by the Democrats, the other half by the Republicans.

And if we had simply picked at random any two states to try to predict the outcome of the election, it would have been ridiculous. Well, similarly, California which is a small fraction of the U.S. which is only one and a half percent of the world's area, tells us nothing about what is happening in the globe. If we, on the other hand, tried to pick out what happened in the 1984 election, in fact, I colored the Democratic states because it was less work, you could have easily picked the election in 1984, because there were only two states that were won by the Democrats. The metaphor is clear.

If you are warming the planet on the order of one degree it is like the 1976 election. You need to wait a long time before you see the trends. But by the time it is warmed up to two and three degrees, which is the equivalent of the global temperature the equivalent of a landslide, then it becomes obvious everywhere. And this gets back again to Senator Gore's point, which is that these events have momentum in them and inertia, which goes over many decades. And if each of us insists on being convinced beyond a doubt that these events are occurring in their own backyard, if they all come from Missouri and have "Show Me" on their license plate, then we simply will be forced to have to go through unprecedented change and the key is to find management strategies which can reduce that change and then try to make sure that those strategies also have additional benefits that we can encourage political acceptance.

Senator WIRTH. Thank you. Gentlemen, we thank you very much for that superb testimony. We understand the fact that this cannot be an ideological issue and is going to require flexibility and understanding on the part of our constituencies, on the part of our political leadership. I am struck by the fact that we have a very mixed message coming out of the administration. On the one hand, some people appear to understand this very clearly at the highest levels of the administration. Others seem to have a kind of ideological inflexibility and do not want to understand it. And I think we have a responsibility to do everything that we can to try to raise the level of awareness and understanding of this, so that we perhaps can open people's minds up to the fact that they are going to have to look at some very different kinds of challenges that we face. Senator Gore, I think put it very well in talking about the fact that this has now become a national security issue for all of us, for our children, for our grandchildren, for the globe overall. And maybe that is the way to do it.

You know, we have all been in a forty year fix thinking about the challenge and the confrontation and the international security ramifications of our relationship with the Soviets, but maybe we ought to just figure out how to use that particular language and transfer that to our relationship with the environment and that will ring some of these guys' bells. I am not sure, you know, what else is going to do it, but we have to keep trying. And your being here and being with us today is helping us along that route, slow and torturous and sometimes frustrating as it may be.

Let me ask Senator Cranston or Senator Gore if you have any final words or questions for the panel.

Senator **Gore**. No.

Senator **Cranston**. I have just one question, if I may. What is the single more important thing you think we could do, in the Senate to advance the effort to cope with this problem?

Dr. **Schneider**. This may be the last time I see Peter look at me first. The single most important thing that we could do would be to set up the incentives, so that the market system can work more effectively, mainly being sure that we charge the more actual costs of our activities, including the environmental costs into the price of fuels and so forth, so that we can see that the system that works well when the prices are right, will be able to encourage efficiency and so forth in the future. If there is one thing we need to do, and I think there is a lot more than one, this is a problem that will take 10 or 15 little things to add up to—we do not have a solution. But if there is any single one, it is let us set up the incentives that will make both individuals and industry use energy more efficiently.

Senator **Cranston**. You mean the cost of energy goes up and the indirect cost of carbon for example, has to be taken into account. We have to pay that cost as well.

Dr. **Schneider**. Yes, I believe we do, but of course, as I said in my remarks, that is an effective way, but then there is a question of fairness because that may impact certain segments of society, the poor and so forth. We would have to work into that mechanism some return of cash to make up for it, but I don't believe that you subsidize properly through artificially low prices of energy. You do it through money.

Senator **Gore**. If I can just say one word. In the past, I have said that I think we may eventually have to move toward a CO_2 tax. That is a tax that takes into account the greenhouse potential for various emissions. But in the meantime, would you agree that in addition to fixing the market signals, that banning the most harmful of the chlorofluorocarbons is the single most important short-term step that could be taken?

Dr. **Schneider**. Yes, in terms of political attractability and the maximum effectiveness with the least hassle, yes, sir.

Dr. **Gleick**. Absolutely. Let me add one point about the state actions that are also relevant and this is true on both the Federal and the State level. In addition to convincing all of your colleagues that this is a critical issue which I think needs to be done, state and Federal projects perhaps need to begin incorporating the issues of climate change into their planning process. Whenever we build something that is going to last 10 or 20 or 30 years and it is funded by state or Federal money, perhaps we ought to require then when we plan such a project to include the impacts of climate change into the process, when we build a reservoir, when we permit a development along the coast, when we price or subsidize water resources, all of those things I think now, need to begin incorporating the issue of climatic change, because we are going to have to deal with the impacts of climatic change in the future. And it is going to cost us money if we wait until those impacts appear to deal with them.

Senator **Gore**. A lot of people are surprised to find out that we already have such requirements, for example, we had testimony in another forum where people planning a long-term water project in South Carolina had to take into account the fact that the sea level was going to be much higher. One of the Cabinet agencies had a commission a contingency plan on what it would take to relocate 60 percent of the population of Florida in the next century.

Dr. **Gleick**. Bit by bit these things are going on in San Francisco Bay. The Bay Development and Conservation Commission is now said, "If you are going to build something along the Bay, you need to take into account future projections of sea level rise". It would be nice to have that quite wide-spread rather than just piecemeal locally.

Dr. **Dracup**. It seems to me that there is an analogy here with the flood control program in the United States, where people within the hundred year flood plain required flood insurance program to purchase flood control if they are going to build in that area. And so, I think that may be a model for our requirements of financial feasibility here.

Senator **Wirth**. Gentlemen, we are very appreciative of your being here. We want to move along, if we might. Mr. Redford is going to join us in the not distant future and as we have told him that we will welcome his testimony when he arrives. What I would like to do, if we might, is to move to our second panel and just keep moving through this. And we will ask Mr. Charles Imbrecht, the Chairman of the California Energy Commission and Mr. James Lents, the Executive Director of the South Coast Air Quality Management District to come up and join us. And perhaps everybody would like to take like a three minute stretch. Why do we not do a stretch in place here and come back to Mr. Imbrecht and Dr. Lents. Gentlemen, thank you very much for joining us. The second panel, we are going to focus in particular on specific responses in California to the issue of global warming. We had some of that discussion earlier with particularly Dr. Gleick and Dr. Dracup. And now we get quite into more of the specifics of implementation. Our first witness, Mr. Charles Imbrecht, Chairman of the California Energy Commission in Sacramento. Mr. Imbrecht also had a distinguished career previously in the California State Legislature. And then we will go to Dr. James Lents, the Executive Director of the South Coast Air Quality Management District. Dr. Lents is a native Tennessean, had a very distinguished career in the State of Colorado and now is in California. So, you could not have hit that much better in terms of this panel, could you, Dr. Lents. Mr. Imbrecht, why do you not start us out and then we will go to you, Dr.

Lents, and then the questions. Your statements, under the rules of the Committee, will be included in the record in full, so please proceed in whatever way you think will be most helpful for the Committee.

STATEMENT OF CHARLES R. IMBRECHT, CHAIRMAN, CALIFORNIA ENERGY COMMISSION, SACRAMENTO, CA

Mr. IMBRECHT. It is a great privilege to be invited to testify before you today and may I take this opportunity to extend formal greetings to our visitors on behalf of my boss, the Governor and certainly on behalf of my colleagues of the members and staff of the California Energy Commission.

By way of background, for those of you that might not be familiar with our agency, we are, in fact, the largest state energy agency in the nation by a factor of about three and a half to one. And our annual budget has ranged from $120 to $150 million dollars annually over the last several years. We have broad responsibilities for forecasting energy requirements in our state, for doing planning for all of our basic infra-structure, for licensing and citing all major energy facilities, including in the event that there was ultimately a demonstrated method of safe nuclear disposal, nuclear facilities. We oversee the bulk of research and development activities by our utilities along a wide range of state-sponsored programs that are unique to the nation. And we also oversee conservation and efficiency investments, incentive programs, the most comprehensive building and appliance standards in the United States in order to reduce our demand. And finally we are in charge of emergency energy planning which have been topics for other hearings.

The Energy Commission is currently leading a multi-agency study examining the impacts of global warming on California as a result of legislation carried this past session by Assemblyman Byron Shure, who is the Chairman of our Assembly's Natural Resources Committee and which, of course, was endorsed by the Governor. It is the last in a series of major air quality bills which the Governor has approved which provided additional police powers to Mr. Lents of the South Coast Air Quality District, which helps bring the South Coast Region into compliance with the National air quality standards, similar to legislation affecting other non-attainment areas in the state along with a very innovative California Clean Air Act that has likewise been enacted in the past two years.

The fact that the Energy Commission was chosen to be the lead agency to deal with global warming, I think reflects the reality that we heard in this morning's presentation. And that is that a great deal of the impacts of global warming are fundamentally questions about how we produce and ultimately consume energy in our modern society. Our study is designed to be comprehensive. It is commissioned by the legislature to be a two-year study but we voluntarily agreed to issue a preliminary report this June and we are in the final stages of inter-agency review before making the preliminary report public. I should mention as well before going on to my substantive remarks, that Speaker Willie Brow, Senator Art Torres, a member of the State Senate and Assemblyman Shure also have comprehensive legislation pending this year that greatly expand the scope of authority of the Commission to deal with the variety of issues that we certainly must confront.

Our tentative conclusion, I am sure will come as no surprise, based upon the best information available. I might add, that we have worked very closely with the University of California and other academic institutions in the state, all of the individuals that were before you this morning, have worked with our staff in our findings. That overall we conclude that the risks and consequences of global warming are clearly great enough to warrant a comprehensive and expedited examination of policy options for delaying or preventing further warming as well as policy to prepare the state for warming that may come in any event, and irrespective of any corrective actions we take at this point in time.

We heard a lot of analogies this morning but to some extent, we are faced with the unpleasant reality that the third may have had capturing the Valdese and that is that once you are directed down a certain course, it is a very, very large ship and you can apply the brakes and the rudders and the engine all at the same time and hopefully, in a coordinated fashion, and yet it still takes a great distance to slow that ship down and ultimately change its course or direction.

Senator **Gore**. It is even harder if the captain is not on the bridge.

Mr. **Imbrecht**. Yes.

Senator **Gore**. Complete that analogy.

Mr. **Imbrecht**. You are absolutely correct. We have dealt with some of those impacts here in California and again, topics for other hearings. While we are proceeding with that second phase of the study that is due to be released to the legislature, I should say, the report to the legislature in June of next year, we have advised all agencies that have related responsibilities that they should minimize all current impacts and activities that might further exacerbate the global warming missions problem we have within California.

Much of this morning's testimony touched on some of the things I was going to say on the likely impacts. Let me give you perhaps just a quick summary overview of what you heard. Water resources, we conclude that there is no clear indication that there will be an increase or decrease in total precipitation, but rather that the warming will reduce, decrease the snow pack storage, will increase winter stream flows and the potential for flooding and decrease summer flows and all of the other attendant impacts that you heard described earlier.

This along with an increased transformation rate is likely to cause a decrease in water deliveries and an increase in warm weather surface water pollution problems as well which is a topic that I did not hear discussed a great deal this morning.

Now, with respect to electrical energy, warming would undoubtedly cause a substantial increase in electricity demand during the summer periods which is when our peak demand occurs as well as negatively impacting hydroelectric supplies from our existing resource development. And I would just urge that as we think through all of the environmental consequences, in fact we are talking about significant retrofit or modifications to our existing hydroelectric system in the state. There is a great deal we are going to have to do with the Federal government to work through all the implications of the environmental consequences for damaging existing wild rivers. And I do not in any way suggest a resolution to this problem, but it is just another one of items on the list that has to be considered.

With respect to agriculture, our industry clearly might be hurt by lower water supplies but at the same time, in order to give a balanced reflection of this issue, it might be helped by a longer growing season and increased growth stimulated by higher levels of carbon dioxide. Agriculture may also be troubled by increased weather variability. Our forestry resources, like agriculture, may benefit from increased concentration of carbon dioxide but the expected increase in summer heat and dryness are likely to distress many of the state's forested areas acutely. Over all California, forests are likely to experience slower growth and higher susceptibility to fires, insects and disease.

Rising ocean level, thermo expansion of the ocean by glacial melting are likely to cause, we believe at least a one-half meter to one and a half meter rise in the ocean level. This rise, however, would follow atmospheric warming by several decades. A one meter rise without increased protection as we heard earlier, would triple the size of the San Francisco Bay system. In terms of the natural habitat, rise in ocean levels and reduced river flows are likely to reduce coastal and delta wetland habitat. These changes could also adversely effect resident and spawning fish populations. A general increase ih temperature and accompanying increase in summer dryness would also adversely affect wetland plant and animal species.

In the region of air quality and human health area, higher temperatures may worsen existing air quality problems. I think Dr. Lents will discuss that in greater detail. And the higher heat rate may also affect health risks for our population. Finally, in terms of the economy, obviously speculation could be very wide, could cause increased prices, decreased trade, increased population growth through immigration because some of the impacts would be even worse in surrounding areas and make California even yet a more attractive end route for people seeking a better climate and decrease tourism, diversions of investment money to warming response activities and an increased uncertainty of investment return.

We have not, as I said, completed the second phase of our study dealing with the specific policy responses to global warming and, we will have those ready within the next calendar year. Nonetheless, I believe I can make some relevant observations. Based on California's energy policy experience, which we do believe is the most innovative in the country, it seems apparent that any strategy for minimizing global warming must depend heavily on reducing emissions of greenhouse gases.

Carbon dioxide is the most significant of these gases and as it turns out, as you have heard, California has had reasonable success reducing fossil fuel consumption and consequent CO_2 emissions. Let me just note for you that during the droughts in 1976 and 1977, we reached a peak where 81 percent of our electricity was actually produced from fossil fuel. That is an extraordinarily high level. On many occasions our dependency was on fossil fuel. We have now reduced that to less than 30 percent. That is an illustration of turning that big ship around in a relatively short period of time, since we do have the largest installed electrical capacity of any area in the nation and I think it also illustrates what can be done on a national basis if, in fact, there is a concerted and strongly bipartisan supported plan to undertake the kind of actions that we have already undertaken in California.

Senator WIRTH. Over what time did you go from——

Mr. IMBRECHT. That is 1977 until today, 12 years later, and actually, we got down below 30 percent about two years ago. So, we have reduced our total dependence during a worst case situation, namely a drought by roughly 50 percent. And while we are still pursuing even additional gain, nonetheless, I think that illustrates, as I said, the success of our combined renewable energy development programs and conservation and demand production problems on either side of the supply and demand equation.

Senator WIRTH. Let me make sure I understand that. California's electrical energy supply, the amount generated by fossil fuels has gone from 80 percent to 30 percent in a 12 year period of time.

Mr. IMBRECHT. That is correct. Now the 80 percent artificially skews that high. On an average basis, we were down to around 65 to 70 percent but during the drought, we actually spiked up to 81 percent, was the actual number. And today, we average less than 30 percent dependence on fossil fuel for our electric generation. That reflects the addition of nuclear generation that was under construction during that time period, but probably more profoundly, it reflects both demand reductions and almost all of our supply additions that occurred during that time period have, in fact been renewable or alternative technologies.

I would be happy to go into the details of that if you would like. I should note here the local environmental and energy security concerns have made reducing fossil fuel use important for California. It appears that strategies to minimize global warming tie in well with the state's environmental and energy security policies currently in place and I might add that we have found a unique centergism between a lot of environmental concerns and energy development that simply did not exist in the past.

Between 1976 and 1986, state-wide emissions of CO_2 shrunk by almost 10 percent after growing over 18 percent in the previous decade. Most of that decline came from the most progressive state energy policies in the United States, promoting energy conservation and increased use of alternative and renewables. These policies were further supported by Federal programs and a general rise in energy prices. I would like to comment further. Some of the Federal programs that are expanded on in your bill, Senator Wirth, S-324, have been remarkably effective tools in promoting energy alternatives within our state. For example, we administer the schools and hospitals program. We have had more than 600 projects in that state where each single dollar of grant has resulted in over $11 in energy savings.

In total, over the last 15 years, California has saved close to $30 billion through energy conservation. The majority of these savings has come as a result of the state's building and appliance standards on top of the incentive programs as well. And I would like to just take a brief second here to note that this is one illustration of where you should carefully refine what you do in terms of global warming on a national basis to look at all of the ramifications of the policy objective.

To flat ban chlorofluorocarbons for all applications, in our judgment, does not make sense until there are substitutes or alternatives. And let me offer a very specific illustration. Only two percent of the CFC's in use in the country today go into our refrigerators, which supports the largest energy consuming appliance in the average home. The only place where CFC's from refrigerators ultimately result in atmospheric emissions are at the time of disposal of the refrigerator, repair, or the coolant system actually leaks the CFC's or disposal of the foam insulation.

As a consequence, if we were to follow the lead of the appliance industry, which has been advocating before USDA that we back off on the new Federal appliance standards that they are now responsible for enforcing, we could see very significant increases in electrical demand and loss of conservation potential over the 20 year life on new refrigerators purchased by the general public with no appreciable impact on the total CFC emission problem. The National Resources Defense Council which has worked very closely with the Commission in the development and rationing up of the standards regularly over the last several years, joins with us in concluding that it is better from an overall global warming perspective not to have a flat ban on CFC's for energy conservation applications when, in fact, that can reduce other carbon emissions, including additional electric generation requirements.

So, as you look to those kinds of applications, I urge you to look at them with a microscope rather than binoculars and understand that all of the policies have to be developed very carefully to minimize total emissions, not just in one simple category. Let me note that in terms of electricity generation, the state now has over 13,000 megawatts of renewable generation on line. That is roughly one-quarter of our total installed capacity which I think also is quite remarkable.

In the transportation area, the Federal CAFE standards have significantly increased the efficiency of California vehicles. At the same time, California has become a leader in developing technology and fuel alternatives to gasoline and diesel fuel vehicles. The Energy Commission has initiated in conjunction with a variety of other state agencies, and Dr. Lents' agency as well, a number of programs to rapidly commercialize vehicles powered by methanol, compressed natural gas and electricity. I drove such a state of the art vehicle to this hearing today, and I welcome you to inspect it, if you would like when we conclude.

Southern California also brought an electric G-van vehicle as well, so you can see what is actually occurring and it is rapidly moving into our streets and highways. Recent trends in energy consumption indicate the demand for all forms of energy is continuing to increase. Of specific concern is the fact that California's gasoline consumption has grown three to five percent per year over the last four years. That simply is unacceptable. Today, we consume more liquid fuel, gasoline and diesel, than any nation on the face of the globe save the cumulative United States and the Soviet Union.

And while we have come close, I think, to solving our risk and problems in the electrical generation area, it is clear that the Achilles' heel of our energy economy is the transportation sector, where we remain 99 percent dependent upon a single base fuel source. And in terms of building an insurance policy for the future of our citizens and our state, it is clear that we have to move and move rapidly, irrespective of all the air quality benefits that are similarly associated with these emissions.

Even without considering the ramifications of global warming, it is clear that energy security and regional environmental issues make it vital that California reduce its overall use of fossil fuels. And as we become more aware of the risks we face from an anthropogenic warming, the imperatives for reducing emissions of CO_2 as well as other greenhouse gases becomes all that more immediate. As your bill, Senator Wirth, clearly recognizes, state governments have a critical role to play in any effort to minimize global warming. California has an energy research and development program that complements that of the Federal Government. In fact, it is the only generic state R and D program in the country.

While the Federal effort emphasizes more basic or so-called fundamental research and development, our programs focus on meeting the needs of end users through applications, research and commercial demonstration programs. I believe our experience in these areas can be a key asset in developing and implementing an overall effort to control greenhouse gas emissions.

I want to stress that we put money not only into the supply side, but into the demand reduction side as well as into advanced pollution control technology options available for a wide range of stationary and mobile source applications. Just a closing observation. The Federal global warming proposals we have reviewed emphasize policies to minimize any future warming. This is, of course, critical but it should not be a singular global warming policy area for the Federal Government to pursue. What may become equally important in the long run are policies to accommodate warming that may be coming in any event. It is obvious from the Commission's impact analysis that even a moderate warming could have dramatic repercussions for most citizens of our state. The State Government is beginning to support policies to accommodate warming and I feel it is appropriate for the Federal Government to focus an effort here as well.

Here again I offer the expertise of our Commission to help develop Federal strategies in this area. I would just like to note for you some of the things quickly that we have undertaken as we say at a minimum to tread water. We have just announced a policy that is already drawing opposition from those in the natural gas community to set aside a minimum of 50 percent of all new future generation in the state for non-fossil fuel based pathologies. They are, of course, that we should look at near term and short term price. We think that that simply cannot be the strategy for the future and we must internalize the externalities, another way of talking about putting a price tag on environmental costs and clean up and so forth, and look at all of those costs on a level playing field at the front end, before we make an investment decision rather than finding out about them after the fact and then having to find the funds to deal with those issues.

Our next electricity report will focus almost exclusively on specific implementation problems to deal with these issues. We think our demand forecasts are sufficiently accurate right now, that we can divert staff for that purpose. I would also just like to note that we are also the only state that has an energy technology export program. We call it "Made in California, Ideas and Technology", designed explicitly to try to assess the third world in implementing stand-alone electrical generation systems for refrigeration, for vaccines, for enough lighting and electricity for education in the evening hours, use of television and so forth for central government's communication. In many of the developing countries the immigration problems are enormous and much of that is occasioned by a natural human desire to have modern conveniences. Without the existing infra-structure and the grid that we have here, it is clear that stand-alone generation such as what we have developed in California, has brought applications. It can mean a very strong economic benefit for our state and I would suggest for the country as well, and yet, at the same time, help deal with some of those international issues that we heard, I think, eloquently described this morning.

So, again, I would like to thank you for the opportunity to be here today. And at the pleasure of the Committee, I would like to submit some detailed observations that we and our staff have compiled on S-342 and we promise to do that within the next few weeks. And finally, I would like to congratulate you on your efforts to deal with an environmental problem that obviously may affect us all for decades to come and particularly to dispel the notion that people in public life do not put in long hours. I think you are to be commended for meeting on this beautiful Saturday and showing that you work well beyond the normal 40 hour work week. Thank you very much.

[The prepared statement of Mr. Imbrecht follows:]

Testimony
of
Charles R. Imbrecht
Chairman, California Energy Commission
Before the
U.S. Senate Energy and Natural Resources Committee
at
Los Angeles, California
May 20, 1989

GOOD AFTERNOON .

I WANT TO THANK YOU FOR THIS OPPORTUNITY TO DISCUSS THE GLOBAL WARMING ISSUE FROM CALIFORNIA'S PERSPECTIVE. THE CALIFORNIA ENERGY COMMISSION IS CURRENTLY LEADING A MULTI-AGENCY STUDY EXAMINING THE IMPACTS GLOBAL WARMING MIGHT HAVE ON CALIFORNIA. THE STUDY GOES BEYOND ENERGY TO LOOK AT ALL AREAS THAT MAY BE AFFECTED BY GLOBAL WARMING. OUR TENTATIVE CONCLUSION WILL COME AS NO SURPRISE -- BASED ON THE BEST INFORMATION AVAILABLE, WE FOUND THE FOLLOWING IMPACTS:

- OVERALL -- THE STUDY FINDS THAT THE RISKS AND CONSEQUENCES OF GLOBAL WARMING ARE GREAT ENOUGH TO WARRANT A THOROUGH EXAMINATION OF POSSIBLE POLICY MEASURES FOR DELAYING OR PREVENTING FURTHER WARMING AS WELL AS POLICIES TO PREPARE THE STATE FOR WARMING THAT MAY COME IN ANY EVENT.

- WATER RESOURCES -- THERE IS NO CLEAR INDICATION WHETHER THERE WILL BE AN INCREASE OR DECREASE IN TOTAL PRECIPITATION. IT IS, HOWEVER, LIKELY THAT A WARMING INDUCED DECREASE IN SNOWPACK STORAGE WILL INCREASE WINTER STREAM FLOWS (AND FLOODING) AND DECREASE SUMMER FLOWS. THIS, ALONG WITH AN INCREASED EVAPOTRANSPIRATION RATE, IS

LIKELY TO CAUSE A DECREASE IN WATER DELIVERIES AND AN INCREASE IN WARM WEATHER SURFACE WATER POLLUTION PROBLEMS.

- ELECTRICAL ENERGY -- WARMING WOULD CAUSE ELECTRICITY DEMAND TO INCREASE AND HYDROELECTRIC SUPPLIES TO DECREASE.

- AGRICULTURE -- THE CALIFORNIA AGRICULTURE INDUSTRY MAY BE HURT BY LOWER WATER SUPPLIES, BUT IT MAY ALSO BE HELPED BY A LONGER GROWING SEASON AND INCREASED GROWTH STIMULATED BY HIGHER LEVELS OF CARBON DIOXIDE. AGRICULTURE MAY ALSO BE TROUBLED BY INCREASED WEATHER VARIABILITY.

- FORESTRY -- LIKE AGRICULTURE, CALIFORNIA FORESTRY MAY BENEFIT FROM INCREASED CONCENTRATIONS OF CARBON DIOXIDE. BUT THE EXPECTED INCREASE IN SUMMER HEAT AND DRYNESS ARE LIKELY TO STRESS MANY OF THE STATE'S FOREST AREAS. OVERALL, CALIFORNIA'S FORESTS ARE LIKELY TO EXPERIENCE LOWER GROWTH AND HIGHER SUSCEPTIBILITY TO FIRES, INSECTS, AND DISEASE.

- RISING OCEAN LEVEL -- THERMAL EXPANSION OF THE OCEAN AND GLACIAL MELTING ARE LIKELY TO CAUSE A .5 TO 1.5 METER RISE IN THE OCEAN LEVEL. THIS RISE, HOWEVER, WOULD FOLLOW ATMOSPHERIC WARMING BY SEVERAL DECADES. A ONE METER RISE, WITHOUT INCREASED PROTECTION, WOULD TRIPLE THE SIZE OF THE SAN FRANCISCO BAY SYSTEM.

- NATURAL HABITAT -- RISING OCEAN LEVELS AND REDUCED SUMMER RIVER FLOWS ARE LIKELY OF REDUCE COASTAL AND DELTA WETLAND HABITAT. THESE CHANGES COULD ALSO ADVERSELY AFFECT RESIDENT AND SPAWNING FISH POPULATIONS. THE GENERAL INCREASE IN TEMPERATURE AND ACCOMPANYING INCREASE IN SUMMER DRYNESS COULD ALSO ADVERSELY AFFECT WILDLAND PLANT AND ANIMAL SPECIES.

- REGIONAL AIR QUALITY AND HUMAN HEALTH -- HIGHER TEMPERATURES MAY WORSEN EXISTING AIR QUALITY PROBLEMS. THE HIGHER HEAT MAY ALSO INCREASE HEALTH RISKS FOR MANY CALIFORNIANS.

- THE CALIFORNIA ECONOMY -- THE STATE'S ECONOMY COULD ALSO BE AFFECTED BY WARMING. WARMING COULD CAUSE INCREASED PRICES, DECREASED TRADE, INCREASED POPULATION GROWTH (IMMIGRATION), DECREASED TOURISM, DIVERSIONS OF INVESTMENT MONEY TO WARMING RESPONSE ACTIVITIES, AND INCREASED UNCERTAINTY OF INVESTMENT RETURNS.

WE HAVE NOT YET COMPLETED THE PHASE OF OUR STUDY DEALING WITH POLICY RESPONSES TO GLOBAL WARMING. WE EXPECT TO HAVE A SET OF DETAILED RECOMMENDATIONS FOR OUR LEGISLATURE AND GOVERNOR IN ABOUT ONE YEAR. THUS I AM NOT ABLE TO GIVE YOU A FINAL SET OF POLICY RECOMMENDATIONS TODAY.

NEVERTHELESS, I BELIEVE I CAN MAKE RELEVANT OBSERVATIONS BASED ON CALIFORNIA'S ENERGY POLICY EXPERIENCE. IT SEEMS APPARENT THAT ANY STRATEGY FOR MINIMIZING GLOBAL WARMING MUST DEPEND HEAVILY ON REDUCING EMISSIONS OF GREENHOUSE GASES. CARBON DIOXIDE IS THE MOST SIGNIFICANT OF THESE GASES, AND, AS IT TURNS OUT, CALIFORNIA HAS HAD REASONABLE SUCCESS REDUCING FOSSIL FUEL CONSUMPTION AND CONSEQUENT CO_2 EMISSIONS. I SHOULD NOTE HERE THAT LOCAL ENVIRONMENTAL AND ENERGY SECURITY CONCERNS HAVE MADE REDUCING FOSSIL FUEL USE IMPORTANT FOR CALIFORNIA. IT APPEARS THAT STRATEGIES TO MINIMIZE GLOBAL WARMING TIE IN WELL WITH THE STATE'S ENVIRONMENTAL AND ENERGY SECURITY POLICIES.

BETWEEN 1976 AND 1986 STATE WIDE EMISSIONS OF CO_2 DECREASED BY ALMOST 10 PERCENT AFTER GROWING OVER 18 PERCENT IN THE PREVIOUS 10 YEARS. MOST OF THAT DECLINE CAME FROM AGGRESSIVE STATE ENERGY POLICIES PROMOTING ENERGY CONSERVATION AND INCREASED USE OF ALTERNATIVE AND RENEWABLE ENERGY TECHNOLOGIES. THESE POLICIES WERE FURTHER SUPPORTED BY FEDERAL PROGRAMS AND [illegible] GENERAL RISE IN ENERGY PRICES.

I NEED TO COMMENT HERE THAT SOME OF THE FEDERAL PROGRAMS THAT ARE EXPANDED IN S324 HAVE BEEN REMARKABLY EFFECTIVE TOOLS IN PROMOTING ENERGY ALTERNATIVES. FOR EXAMPLE, IN THE SCHOOLS AND HOSPITALS PROGRAM, CALIFORNIA HAS HAD MORE THAN 600 PROJECTS

WHERE EACH DOLLAR OF GRANT HAS RESULTED IN OVER ELEVEN DOLLARS IN ENERGY SAVINGS.

IN TOTAL, OVER THE LAST 15 YEARS CALIFORNIA HAS SAVED CLOSE TO 30 BILLION DOLLARS THROUGH ENERGY CONSERVATION (THE MAJORITY OF THESE SAVINGS HAVE COME AS A RESULT OF THE STATE'S BUILDING AND APPLIANCE STANDARDS). IN TERMS OF ELECTRICITY GENERATION, THE STATE NOW HAS OVER 13,000 MEGAWATTS OF RENEWABLE GENERATION ON LINE.

IN TRANSPORTATION, THE FEDERAL CAFE STANDARDS HAVE SIGNIFICANTLY INCREASED THE EFFICIENCY OF CALIFORNIA VEHICLES. AT THE SAME TIME, CALIFORNIA HAS BECOME A LEADER IN DEVELOPING TECHNOLOGY AND FUEL ALTERNATIVES TO GASOLINE AND DIESEL FUELED VEHICLES. THE ENERGY COMMISSION HAS INITIATED (IN CONJUNCTION WITH OTHER STATE AGENCIES) A NUMBER OF PROGRAMS TO COMMERCIALIZE VEHICLES POWERED BY METHANOL, COMPRESSED NATURAL GAS, AND ELECTRICITY.

RECENT TRENDS IN ENERGY CONSUMPTION INDICATE THAT DEMAND FOR ALL FORMS OF ENERGY IS CONTINUING TO INCREASE. OF SPECIFIC CONCERN IS THE FACT THAT CALIFORNIA'S GASOLINE CONSUMPTION HAS GROWN THREE TO FIVE PERCENT PER YEAR OVER THE LAST FOUR YEARS.

EVEN WITHOUT CONSIDERING THE RAMIFICATIONS OF GLOBAL WARMING, IT IS CLEAR THAT ENERGY SECURITY AND REGIONAL ENVIRONMENTAL ISSUES MAKE IT VITAL THAT CALIFORNIA REDUCE ITS OVERALL USE OF FOSSIL FUELS. AS WE BECOME MORE AWARE OF THE RISKS WE FACE FROM AN ANTHROPOGENIC WARMING, THE IMPERATIVE FOR REDUCING EMISSIONS OF CO_2 AS WELL AS OTHER GREENHOUSE GASES BECOMES ALL THAT MORE IMMEDIATE.

AS THE WIRTH BILL CLEARLY RECOGNIZES, STATE GOVERNMENTS HAVE A CRITICAL ROLE TO PLAY IN ANY EFFORT TO MINIMIZE GLOBAL WARMING. CALIFORNIA HAS AN ENERGY RD&D PROGRAM THAT COMPLIMENTS THAT OF THE FEDERAL GOVERNMENT. WHILE THE FEDERAL EFFORT EMPHASIZES MORE FUNDAMENTAL R&D, OUR PROGRAMS FOCUS ON MEETING THE NEEDS OF END-USERS THROUGH APPLICATIONS RESEARCH AND COMMERCIAL DEMONSTRATION PROGRAMS. I BELIEVE OUR EXPERIENCE IN THESE AREAS CAN BE A VERY

ASSET IN DEVELOPING AND IMPLEMENTING AN OVERALL EFFORT TO CONTROL GREENHOUSE GAS EMISSIONS.

A CLOSING OBSERVATION: THE FEDERAL GLOBAL WARMING PROPOSALS WE HAVE REVIEWED EMPHASIZE POLICIES TO MINIMIZE ANY FUTURE WARMING. THIS IS A CRITICAL BUT NOT SINGULAR GLOBAL WARMING POLICY AREA. WHAT MAY BECOME EQUALLY IMPORTANT IN THE LONG RUN ARE POLICIES TO ACCOMMODATE WARMING THAT MAY COME IN ANY EVENT. IT IS OBVIOUS FROM THE COMMISSION'S IMPACT ANALYSIS THAT EVEN A MODERATE WARMING COULD HAVE DRAMATIC REPERCUSSIONS FOR MOST CALIFORNIANS. THE STATE GOVERNMENT IS BEGINNING TO EXPLORE POLICIES TO ACCOMMODATE WARMING, AND I FEEL IT IS APPROPRIATE FOR THE FEDERAL GOVERNMENT TO FOCUS SOME EFFORT HERE AS WELL. HERE AGAIN, I OFFER THE EXPERTISE OF THE ENERGY COMMISSION TO HELP DEVELOP FEDERAL STRATEGIES IN THIS AREA.

AGAIN, I WANT TO THANK YOU FOR THE OPPORTUNITY TO BE HERE TODAY. AT THE PLEASURE OF THE COMMITTEE, I WOULD LIKE TO SUBMIT DETAILED OBSERVATIONS ON S324 WITHIN THE NEXT FEW WEEKS. FINALLY, I WANT TO CONGRATULATE YOUR EFFORTS TO DEAL WITH AN ENVIRONMENTAL PROBLEM THAT MAY AFFECT ALL OF US FOR DECADES TO COME.

Senator **Wirth**. Thank you very much for a very impressive presentation. And if we have dispelled the notion that public officials do not work long and hard hours, you have dispelled the growing notion that a Republican administration cannot have an enlightened energy policy. We appreciate that very much.

Mr. **Imbrecht**. Thank you very much.

Senator **Wirth**. Dr. Lents.

STATEMENT OF DR. JAMES LENTS, EXECUTIVE OFFICER, SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT, EL MONTE, CA

Dr. **Lents**. Yes. For the record, my name is James M. Lents and I am Executive Officer for the South Coast Quality Management District. Before I get into discussion of my issues, I would like to tell you a little bit about our district. We represent four counties in this area and 11.3 million people. If projections hold true, we will be 15.5 million people over the next 20 years. As we stand today, one in 25 Americans lives in the Los Angeles area. So, it is hard to believe that sometimes those of us regulating this area ourselves do not appreciate the magnitude of the difficulty in addressing some of these problems. There is great interest in this state in the global environmental effects. In fact, I just counted before this hearing, there are at least 16 bills, maybe more by now, in the State legislature in attempts to deal with global environmental issues.

We are bringing forth a rule and a proposed rule to reduce emissions from foam blowing in this area which uses quite a bit of CFC's, about 85 percent and we are working on a policy that would result in a requirement to remove cholofiourocarbons from appliances and such when they are disposed in this area. So, we are attempting to do some minimal things in this area both as a state and, I believe, as an agency with the authority that we have.

As you may know, we have been very involved in bringing forth an air quality management plan for this area in an attempt to show how over the next twenty years, Los Angeles could have healthy air. And we are very proud of that effort. But that is not what I wanted to talk to you about this morning. In particular, I wanted to bring maybe a different message than the other speakers have brought to you today. And that message is, officially, we do not know anything about the greenhouse effect. Officially, we are not doing anything about it in our agency. The Clean Air Act as it stands today in attempting to address 88 urban areas we've talked about that are non-attainment, have no guidance or no direction as to what to do and how to fill those plans in. And I would like to show you some information out where there is some very serious and very real connections between what we attempt to do to solve local environmental problems and what needs to be done in addressing global environmental problems. And I think that it is very important that we pass a Clean Air Act and I certainly want to urge you to support a Clean Air Act like that that has been brought forward by Congressman Waxman just recently.

I also want to urge you to consider how we can provide a linkage between those of us developing plans to clean up local environmental problems and those of us interested in the global warming. So, if you will allow me, I will move over here to the overhead and try to present some information to you.

Because we did not particularly consider the greenhouse effect as we developed our plan, I was nervous as I started to do this program, what was the impact, for instance on carbon dioxide, of our new 20 year program? And at least I have some good news in that effort. This graph will show you, presently there is about 600,000 tons a day for example, of carbon dioxide going into the air in the Los Angeles area. If we do not do our plan, we would expect—because of transportation needs and other changes in this area, for that to go up to 800,000 tons per day. At least, with the plan we have brought forward, it will be held to an increase to 710,000 tons per day. Unfortunately, I cannot say that we are going to cut back, but the plan helps to a degree.

As I am going to show you later, it is possible that as we look—had we considered this more and should consider it in the future, maybe there are ways to adjust our plan to lower that to a point where we could see the reduction or certainly not an increase. This is a per capita decrease because in developing our plan, we are projecting a population growth in this area of almost 50 percent. This represents about a 14 percent decrease in per capita carbon dioxide emissions.

From our viewpoint, I guess this graph is the most alarming of the things I am going to present to you. On the right in the check represents the reactive organic gases and nitrogen oxides being dumped into the air in Los Angeles at the present time. As you can see, about a thousand tons a day of nitrogen oxides and a little over twelve hundred tons a day of reactive organic gases, that is evaporating gasoline, paints drying and those kinds of emissions. Those are the emissions that work together to give us some of our most critical environmental problems, including ozone, nitrogen oxides, fine particulates, acid fogs, et cetera.

Our plan projects taking those down to about 200 tons per day each by the year 2010. Assuming the global atmospheric conditions are the same as they are today, that would bring us down then from 1985 from a violation of some Federal standard on 232 days a year in this basin out of the 365 to meeting them every day of the year in this basin. But we did a little bit of modeling, assuming these are worse case and they should be considered directional rather than absolute values, but we did some modeling looking at what happens if the ultra-violet radiation goes up the way some people project and what if the temperatures go up, because if you have more ultra-violet radiation and you have hotter temperatures, the ozone formation rate increases. As you can see, this tremendous reduction in emissions that we would get would still leave us twice the national ozone standard.

So, not only might we contribute with the problem, the global problem is going to inhibit our ability to solve these localized ozone problems.

Senator GORE. What degree of warming and degree of UVB increase are you——

Dr. LENTS. I do not recall. I know it was at the upper end of some of the projections. Again, it was just to establish the principle that you heard from some of the earlier presenters.

There is a linkage here and we need to think about that. Now, let us talk about some individual things in our plan and how maybe they could be pursued further or should be pursued further.

Transportation control is an important issue and dealing with transportation problems in this area and dealing with environmental problems. It is also one of the most difficult areas to deal with. But as we address them—and this shows what we have projected in our plan—and clearly not only does it give us reactive organic gas emissions and nitrogen oxide emissions, it gives us CO_2 reductions and emissions. I had hoped when we started out to produce a plan for this area that would leave us with driving levels at about the same level we have today, that we would accept this growth each year, by coming up with transportation control measures that would absorb it into the existing system. We were not able to do that.

We actually project a 30 percent increase in driving which in one sense is good, given that we are projecting a 50 percent increase in population. But in many ways the question I have, could that have been pursued further? And clearly, I know from my experience in Denver that there is always a tendency to want to solve things technologically rather than talking about lifestyle changes and are we willing to deal with some of the transportation issues that need to be there and in trying to address the local environmental problems maybe we should pursue the transportation issues a little stronger than we have because there is other advantages to it.

This looks a little bit about the CAFE credits. We do not think of the CAFE credits as having any air pollution benefit. They are talked about as possibly global warming and possibly as secure—energy security measures. But, if our cars are more fuel efficient, then we have to fill them up and——

Senator WIRTH. Explain to everybody what CAFE means?

Dr. LENTS. Okay. These are the fuel economy standards that are set for automobiles and there is a lot of argument on whether to tighten them up or loosen them. We hope that we do not have many gasoline vehicles operating in the Los Angeles area come 2010 based on our plan. But we did a hypothetical calculation just to illustrate the linkage. Today that average, I think, gas mileage of vehicles on the road is about 14.5 miles per gallon. If that were taken to 29 miles per gallon, as you can see, the emissions—this is just from handling fuel, filling automobiles up, carrying it from the distributor to the service station, producing it at the refineries, would be reduced in half. That is 30 tons a day.

We had to regulate the entire furniture manufacturing industry in Los Angeles affecting 50,000 jobs very extremely heavily in order to achieve this much emission reductions that would be changed by pushing the fleet up to 29 miles per gallon. So, again there is a linkage between that decision and some of our decisions to clean up the air.

Here is another issue. We have talked a lot about energy conservation. There are lots of ways to conserve energy from—we talked about in our plan, about not allowing people to use natural gas to heat swimming pools in this area, by saying, "If we are going to heat swimming pools it ought to be done with solar energy". We talked about getting more efficient refrigerators. This helps us in two ways. One, we would like to see a lot more electricity usage and if we see more electricity usage, clearly we need more electricity. There are two ways to get electricity. One is to build new power plants. But, another way is to conserve in existing ways and thus make more electricity available that way.

We believe there is considerable room for energy conservation that would help us solve nitrogen oxide problems in the area as well as help address carbon dioxide pollution. We are regulating our power plants in this area in order to reduce nitrogen oxides. We feel like that is important to the clean up. There are several ways to go about it. One is to add on control equipment. Another way is to go back and fundamentally redesign some of the power plants. In the long run, I think it is cheaper if we would fundamentally redesign the power plants to make them more efficient. We are attempting to design a regulation that would encourage that, but it would be useful, I think, if Congress and the state would work with us to try to force that. We would get the cleaner air from the cleaner power, more efficient power plants and the reduced carbon dioxide from that.

Finally, clean fuels have been a big issue out here. We have been looking forward to trying to get much cleaner fuel vehicles into the fleet. And again, I do not suggest that you use the absolute value of these numbers as much as the directional indications. As we move away from gasoline toward a number of clean fuel options that we think are very realistic and are pursuing, you can see that not only do we get reactive organic and nitrogen oxide emission reductions in our local area, we also get CO_2 emission reductions and some—to varying degrees depending upon the fuel.

The left-hand column shows gasoline and just chooses at 100 or—then we talk about if all our vehicles were operating on natural gas or methanol or electricity, what kind of carbon dioxide shifts would be. That depends, of course, on what you assume about the efficiency of electrical generation in the case of electricity, what you assume about how the methanol was generated, et cetera, and what conclusions you reach on that.

But the point I was attempting to make to you was, as we look toward cleaner fuels to address our environmental problems, there is a way to choose those cleaner fuels and push the technology that can deal with global problems as well.

Senator **Gore**. On the methanol, is that host conversion? In other words, do you start measuring the CO_2 emissions after the methanol has been——

Dr. **Lents**. No, this—I believe this calculation assumes that the whole process, is made out of natural gas, not coal. I know that Mr. Imbrecht could discuss that in a great more detail than I could. That is the conclusion of my remarks. As I said, I want to encourage you—and I think it is very important that you develop global warming policies and regulations. I think it is important that you infiltrate that back into the local agencies who are developing clean air plans who could influence the policy and the decisions we make and how we make them that we can have both clean local environments and also help us out some globally.

[The prepared statement of Dr. Lents follows:]

SENATE ENERGY COMMITTEE HEARING ON GLOBAL WARMING
May 20, 1989 in Los Angeles, California

TESTIMONY OF

JAMES M. LENTS, Ph.D.

Executive Officer of the
South Coast Air Quality Management District

Mr. Chairman and Members of the Committee, I am Dr. James M. Lents, Executive Officer, of the South Coast Air Quality Management District ("District"). I am here today because the South Coast Air Quality Management District is very concerned about the potential adverse effects of global warming on public health and welfare. As the prime agency responsible for meeting air quality standards in this area, we are especially concerned that global warming will inhibit our ability to meet federal clean air standards. The specific concerns I will be raising are also likely applicable to some of the other federal non-attainment areas. The thrust of my comments will be that programs to meet federal air quality standards must be combined with aggressive efforts to address global warming in a coordinated fashion.

South Coast Air Basin

As alluded to earlier, the District has responsibility for attaining healthful air in the South Coast Air Basin. The Basin is comprised of the urban and non-desert potions of Los Angeles, San Bernardino and Riverside counties, and all of Orange County. The current population in the Basin is approximately 11.3 million people and it is expected to increase to 15.5 million people within the next twenty years. Today, one out of every 25 Americans lives in the Basin. During 1988, the region exceeded one or more of the federal clean air standards on 232 days of the year.

Chloroflourocarbons

A number of programs are underway within California to reduce the use of chloroflourocarbons (CFCs) in the District and in most cases statewide. There are at least sixteen bills now before the state legislature that are intended to reduce CFCs or otherwise address ozone depletion and global warming. The District is developing a rule using its existing authority to reduce CFC emissions. This rule will control emissions of reactive hydrocarbons, methylene chloride (a toxic air contaminant), and "hard" CFCs by at least 85 percent from polystyrene and polyurethane foam products. We are also developing a general policy regarding the phase out of CFCs intended to address other uses of CFCs including disposal of products containing them.

Global Warming and Stratospheric Ozone Depletion Effects on Achieving Federal Clean Air Standards.

We recognize that global warming and stratospheric ozone depletion are issues requiring *national and international attention and cooperation. The potential impacts of these phenomenon on climate, regional weather, sea level, and public health and welfare could be catastrophic. Since the United States produces nearly 25 percent of all carbon dioxide emissions on our planet, we are obliged to assume a leadership role in the international effort to address global warming.*

The potential impacts of these global problems on our ability to protect public health and welfare relative to the federal ozone standard is also of major concern. It is this latter concern that I will discuss in detail.

In our region, ozone concentrations can be as much as 3 times the, health-based, National Ambient Air Quality Standard. A recently completed revision to our region's Air Quality Management Plan calls for an 80% reduction in emissions of reactive organic gases (ROG) and nitrogen oxides (NOx) to achieve the standard. Such a level of emission reduction will require full use of known technology and major technological innovations. Over 122 pollutant control measures have been identified and their implementation will ultimately change many aspects of our lives.

Increases in global temperature and ultraviolet radiation could wipe out gains to be made from implementing these measures and destroy our chances of meeting the federal ozone standard. Recent modeling studies indicate that projected ozone concentrations in the Basin could be as much as twice *the federal standard, even with an 80% emission reduction, if recent predictions of future warming and stratospheric ozone depletion occur. This change would nullify most of the improvement which would be made through our 20 year clean-up Plan. I believe this adds another dimension to the issue before you which has not received adequate attention.*

The 1989 Air Quality Management Plan for the South Coast Air Basin

The 1989 revision to the Air Quality Management Plan for the South Coast Air Basin contains a number of actions which serendipitously reduce emissions of greenhouse gases as well as criteria pollutants. We estimate that the Plan will reduce per capita carbon dioxide emissions within our region by about 14 percent (Figure 1). However, because of population growth, total carbon dioxide emissions will increase by about 18 percent.

The two most important components of the Plan relative to reducing carbon dioxide emissions are: transportation control and energy conservation measures. Our Plan commits to a 27 percent reduction in vehicle miles travelled through implementation of transportation control measures and a 20 percent reduction in natural gas use through energy conservation measures. A listing of these measures is contained in Exhibit 1 and many of these measures could be reasonably implemented outside of Southern California. In addition to these measures, improving average motor vehicle fuel efficiency through more stringent federal CAFE standards would significantly reduce carbon dioxide emissions and would result in less reactive organic gas emissions.

The Plan also includes additional initiatives which will reduce greenhouse gases and stratospheric ozone depletion through control of stationary sources. The more notable actions include more stringent emission limits on power plants, control of emissions from polystyrene and polyurethane foam blowing, and adoption of a phase out policy for chlorofluorocarbons.

With respect to power plants, a new rule is under consideration for the South Coast Air

Basin which sets limits based on pounds of pollution emitted per megawatt-hour of electricity produced. This rule is needed to reduce nitrogen oxide emissions. Nitrogen oxide reductions are essential to enable this area to meet national health standards for fine paticulates and ozone. In addition, a reduction in nitrogen dioxides will also reduce acid fog and related health and corrosion effects, will reduce the creation of potentially carcinogenic nitrated organics, and will greatly improve visibility in the Basin.

The rule approach we have chosen can result in reduced carbon dioxide and nitrous oxide emission reductions as well . It will encourage the replacement of older less efficient power plant units with newer, more efficient equipment such as repowered combined cycled systems. Such equipment can increase fuel efficiency of various power plants by 20 to 50 percent, and will result in a proportional decrease in carbon dioxide and nitrous oxide emissions. In addition, the rule will provide incentives for the use of technologies which do not involve fossil fuel combustion such as solar, wind, and geothermal power production.

Alternative fuels

Another significant portion of our planning and regulatory effort is in the area of alternative fuel use. It will be virtually impossible for the South Coast Air Basin to attain all federal clean air standards unless we eliminate the use of some traditional fossil fuels such as diesel, fuel oil, and possibly gasoline. In this regard, we are examining a number of clean burning alternatives including methanol, liquefied petroleum gas, natural gas, hydrogen power, and electricity.

We recognize that global warming should be a primary consideration in the selection of fuels to be financially supported for development and commercialization. There are clearly significant distinctions among the alternative fuels as to their relative impacts on global warming. For vehicles, these distinctions should be understood in terms of emissions of greenhouse gases per mile travelled. These gases consist primarily of carbon dioxide with smaller contributions from methane. Although additional studies are needed to definitively rate alternatives according to this criteria, preliminary studies indicate that several alternative fuels will reduce carbon dioxide emissions relative to gasoline.

Recommendations

The South Coast Air Quality Management District proposes that the following measures be considered by the Committee to reduce global warming:

- *Congress should create a process that merges the development of clean air plans with the development of programs to address global environmental issues. This could be accomplished through coordination of control efforts for criteria pollutants and greenhouse gases. U.S. Environmental Protection Agency assistance should be made available to provide guidance to local areas relative to control options.*

- *Congress should promulgate more stringent national standards/guidelines for fuel-use efficiency. This will provide progress toward several objectives, including reduced carbon dioxide emissions, reduced criteria pollutant emissions, and* *progress toward limiting our dependence on foreign fuel supplies.*

- *Congress should require all federal facilities to take actions to reduce their emissions of greenhouse gases and should establish emission standards for sources that are best controlled at the national level. This includes Outer Continental Shelf operations, trains, ships, and planes.*

- *Congress should require appropriate research relative to global warming. The first phase of such research should focus on identifying near-term programs which provide for healthy air quality and long-term atmospheric protection.*

Lastly, Congress should fund research aimed at reducing carbon dioxide emissions from burning fossil fuels. The results of such research should be provided to developing industrial countries which have large populations and burn significant amounts of fossil fuels. These countries will be the major contributors to greenhouse gases in the future and their emissions must be curtailed, along with those of the United States.

Exhibit 1

Transportation Control Measures

Employer Rideshare (Regulation XV)
Alternative work weeks and flex-time.
Telecommunications.
Transit incentives.
Parking management (charge for parking).
Vanpool purchase incentives.
Merchant transportation incentives.
Auto use restrictions (event center park & ride).
HOV (high occupancy vehicle) facilities.
Transit improvements (regional mobility).
Truck dispatching/rescheduling/rerouting.
Diverting port-related truck traffic to rail.
Traffic flow improvements.
Nonrecurrent congestion [response].
Rail consolidation to reduce grade crossings.
Freeway capacity enhancements.
Railroad electrification.
High-speed rail.

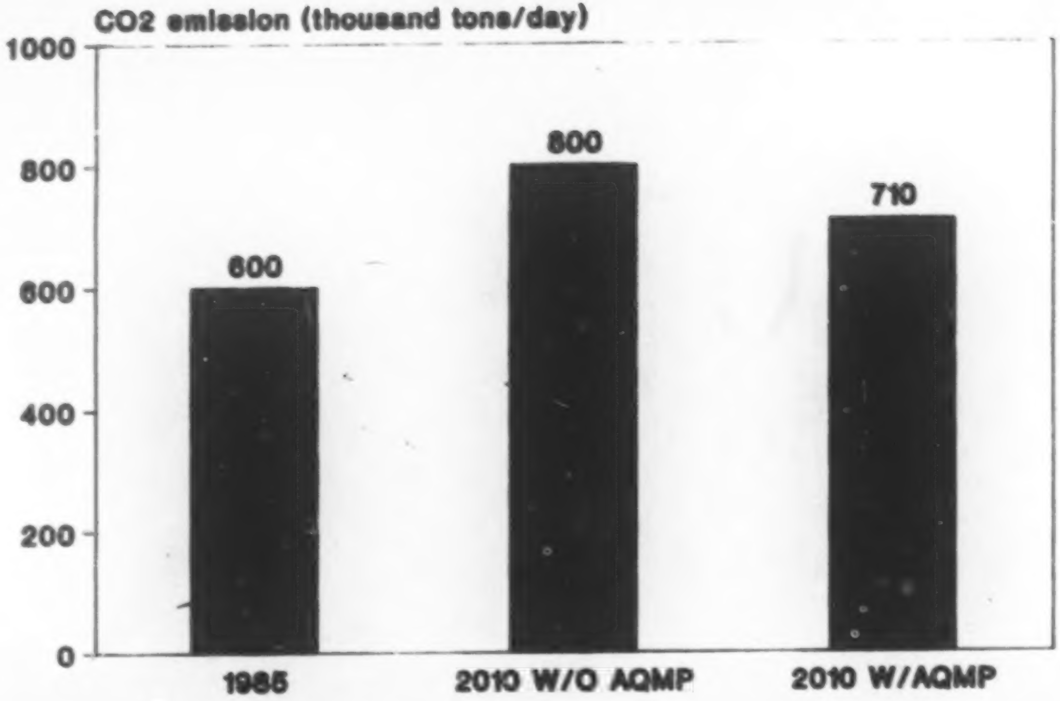
Utility

Stationary Gas Turbines (Steam Injection and SCR).
Electric Power Generating Boilers (Repowering, SCR, and other methods).

Energy Conservation

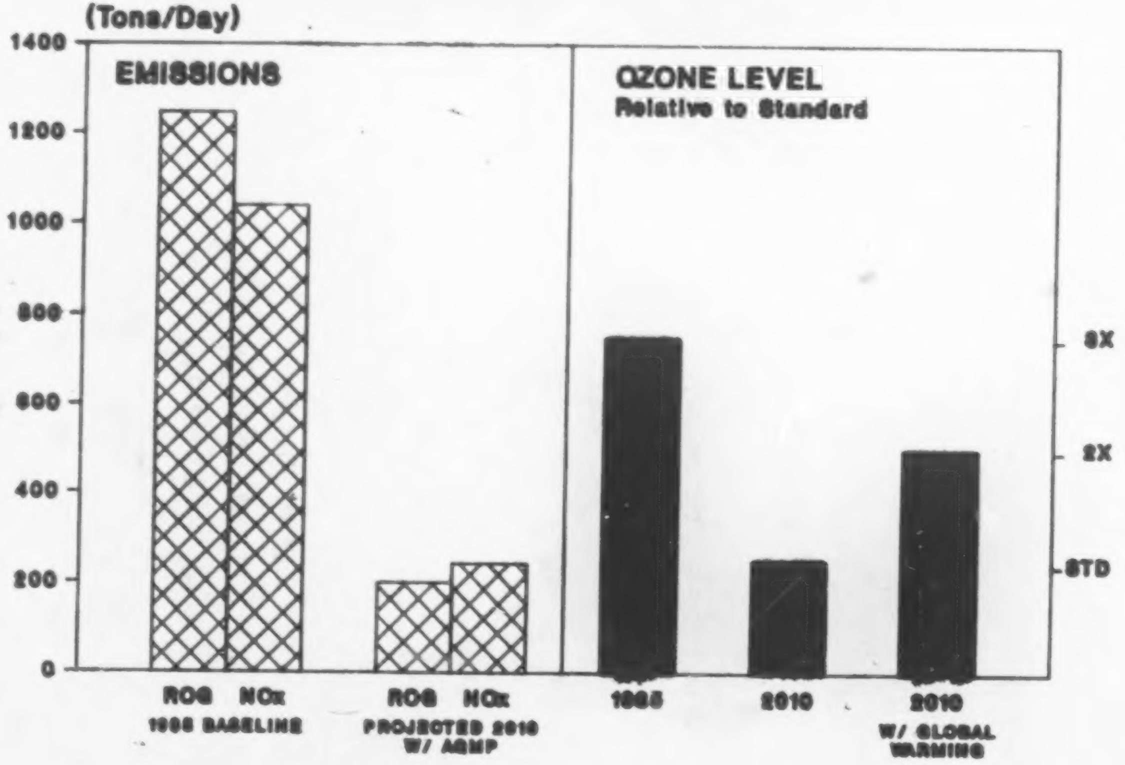
Pricing, Tax, and Subsidy Incentives.
Waste Recycling (mandatory requirements).
Local Government Energy Conservation (administrative procedures).

Effect of AQMP on CO2 Emission in the South Coast Air Basin*



*Including out-of-basin power generation

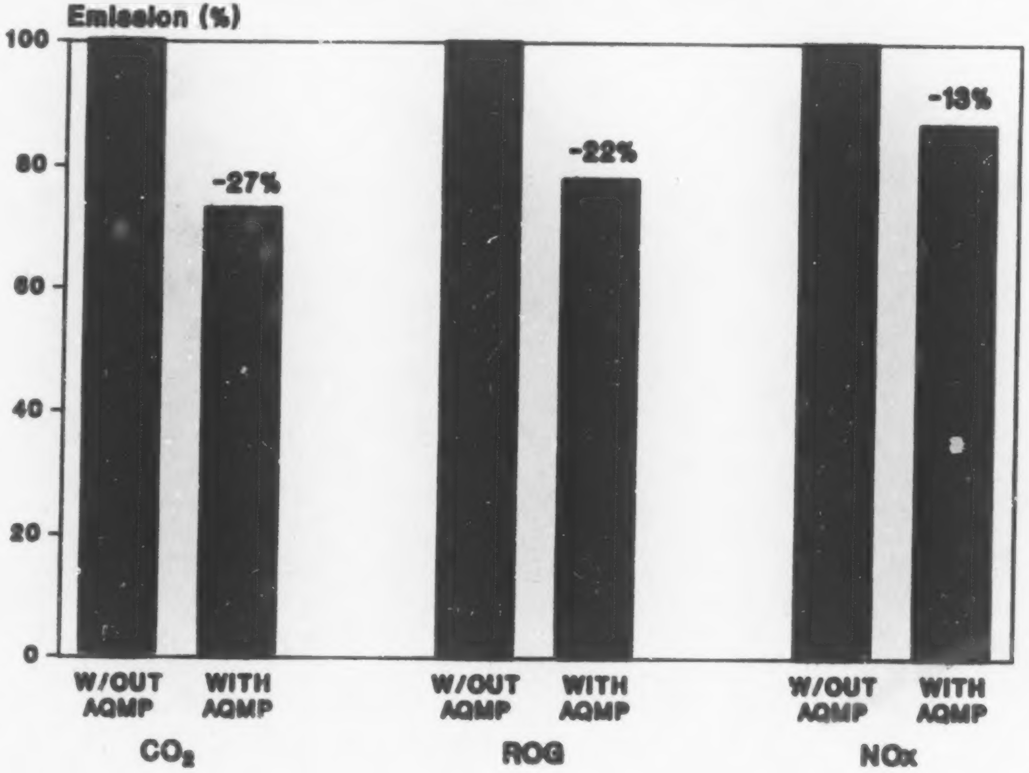
Effect of Global Warming on Ozone Attainment in the South Coast Air Basin



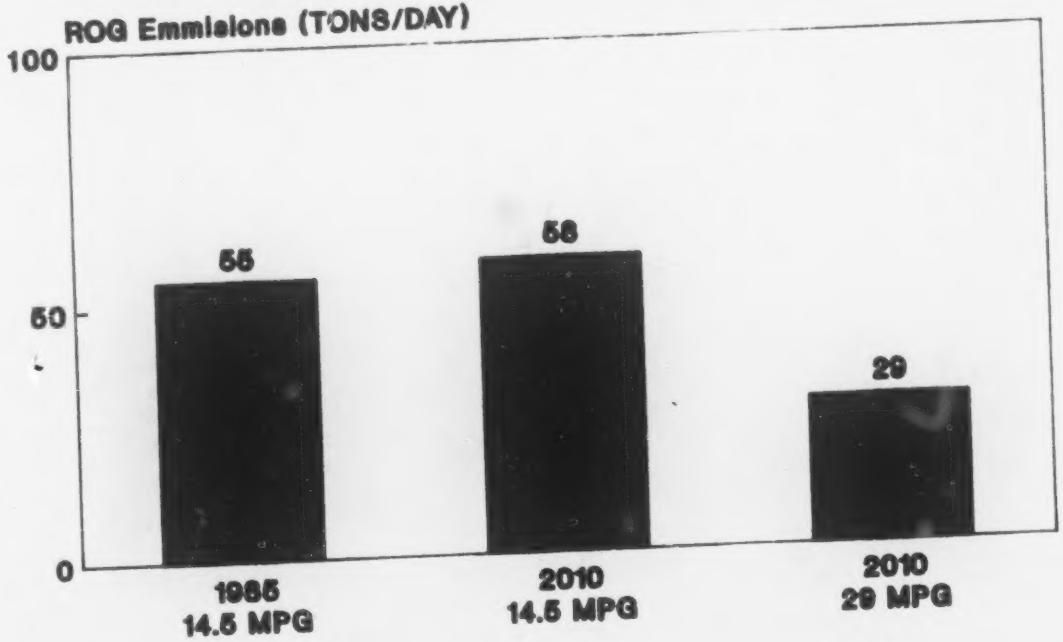
COMMON CONTROL APPROACHES (GREENHOUSE GASES & CRITERIA POLLUTANTS)

- TRANSPORTATION MANAGEMENT
  - TRIP REDUCTION MEASURES
- FUEL ECONOMY
  - CAFE STANDARDS
- HOUSEHOLD EFFICIENCY
  - IMPROVED HEATING AND COOLING SYSTEMS
- REPOWERING
  - COMBINED CYCLE POWER PLANTS
- CLEAN FUELS
  - NATURAL GAS
  - METHANOL
  - ELECTRICITY

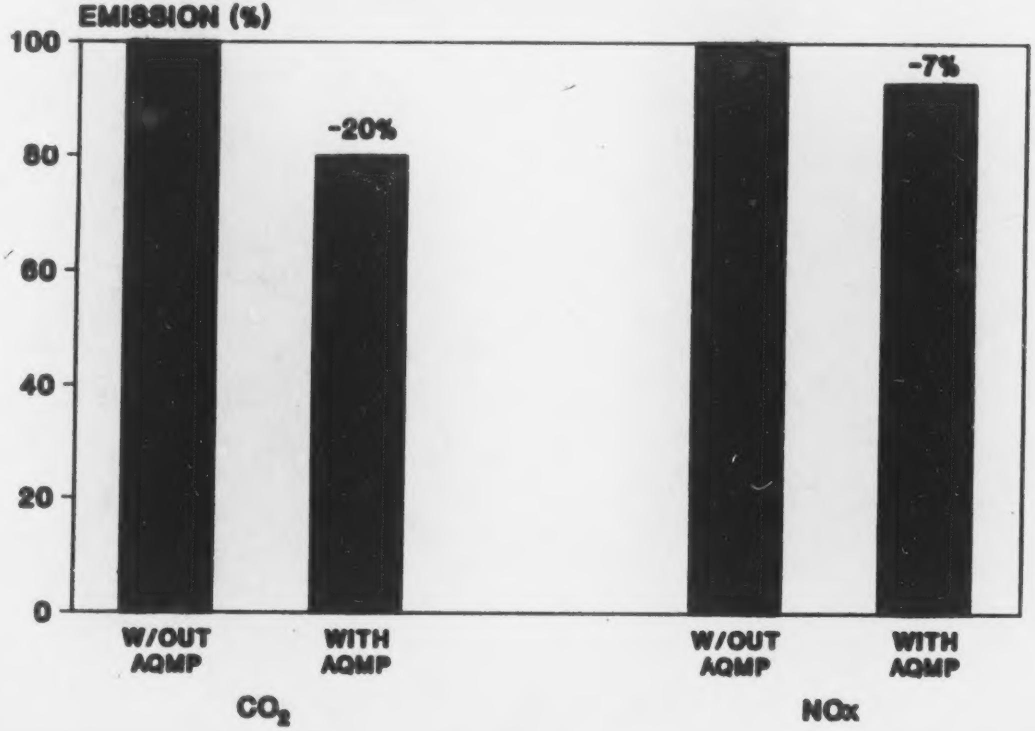
TRANSPORTATION MANAGEMENT



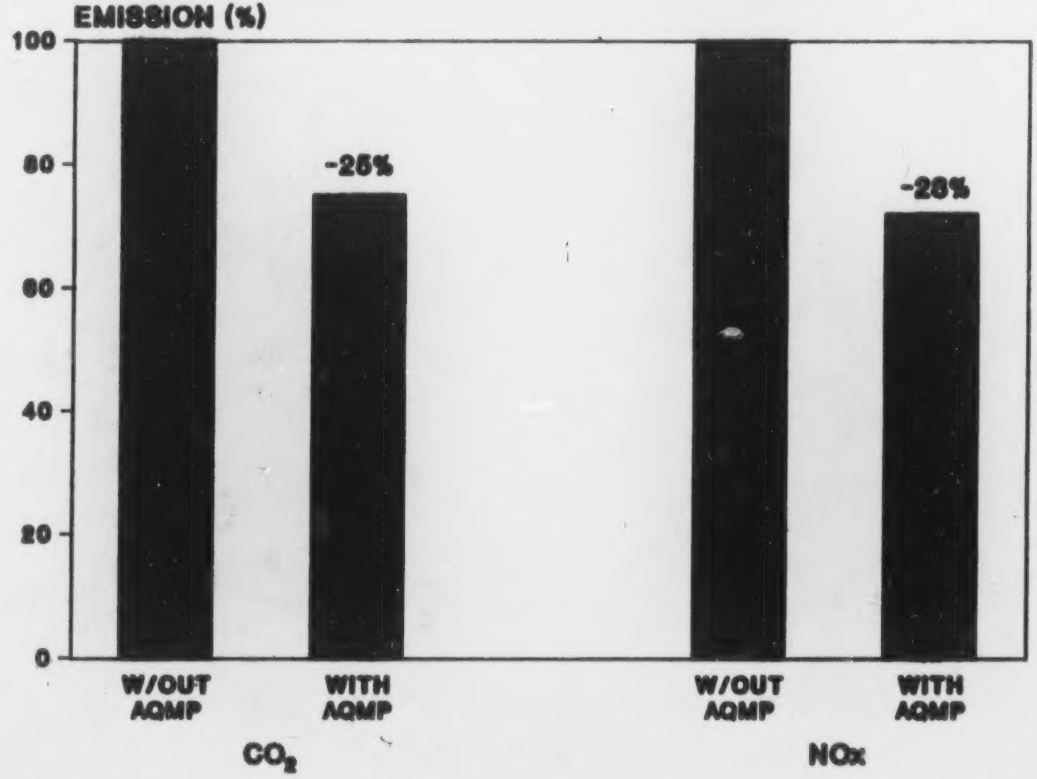
ROG EMISSIONS REDUCTION FROM MORE STRINGENT CAFE STANDARDS (PETROLEUM REFINING AND DISTRIBUTION)



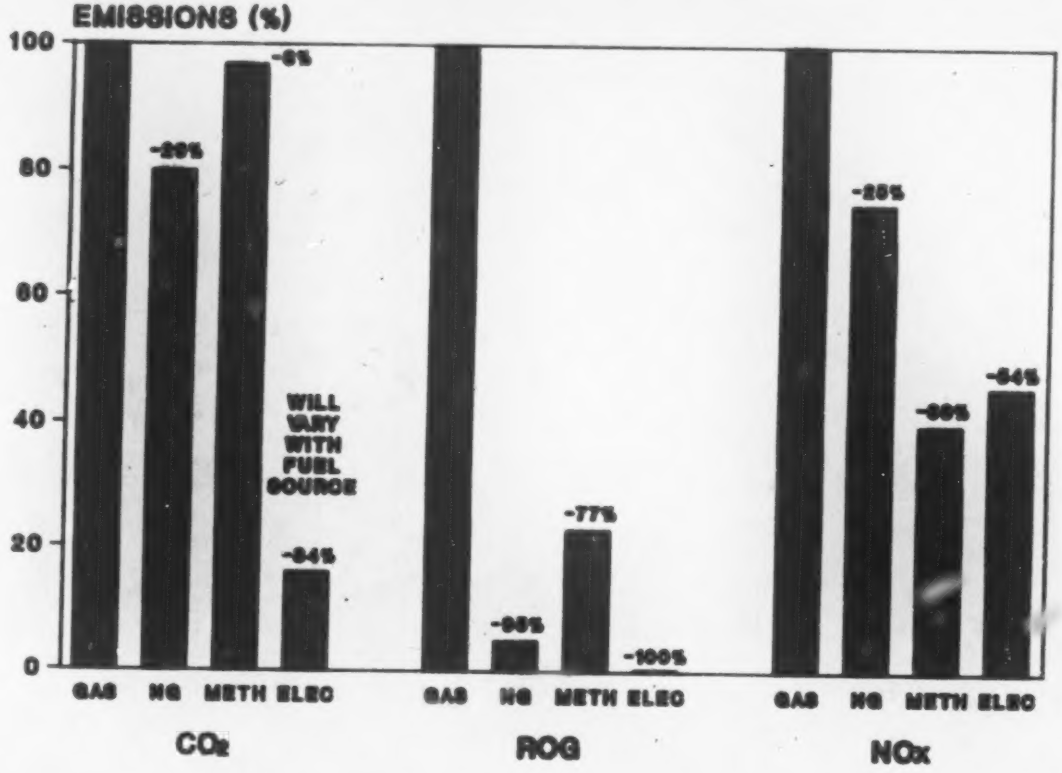
ENERGY CONSERVATION
REMAINING EMISSIONS(STATIONARY SOURCE)



REPOWERING OF POWER PLANTS



CLEAN FUELS
PASSENGER CARS



RECOMMENDATIONS

- COORDINATED PROCESS FOR CLEAN AIR PLANS AND PROGRAMS ADDRESSING GLOBAL ATMOSPHERIC ISSUES

- MORE STRINGENT NATIONAL STANDARDS FOR FUEL USE EFFICIENCY

- EMISSION CONTROLS FOR GREENHOUSE GASES
  - FEDERAL FACILITIES
  - SOURCES SUBJECT TO FEDERAL JURISDICTION

- ADDITIONAL RESEARCH RELATED TO AIR QUALITY AND GLOBAL WARMING

Senator WIRTH. Thank you very much. Let me point out for the people who have been with us here for the morning or have recently joined us, I hope we are going to have a little bit of time at the end of this for questions from the floor. So, I just want to point that out, if any of you are interested in doing so.

Let me go back and first of all, take it from the top to pick up again on the question that Alan Cranston asked earlier. If you were, Mr. Imbrecht, sitting where we are, what would be, from your perspective, the most important things that we can be doing in the United States Senate?

Mr. IMBRECHT. I think the single—the single activity that could probably have the nearest term impact would be a very aggressive program to insure that the existing bank of CFC's that are in mechanical devices throughout this country are recaptured rather than released in the atmosphere. And I would just suggest a couple of options for you in that context. Most of the municipal bus fleets in this country today recycle their CFC's from the refrigeration or air conditioning systems driven largely by economics.

It is really not a complicated process. And rather than—when they recharge the air conditioning system, they vent it not into the atmosphere as is the case of most service stations or car dealerships, but rather into a recapturing system. I would think that something of that nature should be looked at quickly and with a nation-wide perspective.

Secondly——

Senator GORE. Could I just jump in on that point because I have legislation pending that would do exactly that and regulate the recharging of automobile air conditioning units that are now vented and other sources of CFC vents and ban the consumer products that are still in the marketplace. For example, you can go down to any auto parts store in Los Angeles and get little cans of freon off the——

Mr. IMBRECHT. And do it yourself.

Senator GORE [continuing]. Shelf and do it yourself and can contribute directly. These air horns, which ought to be banned for other reasons anyway, that make so much noise. I mean, there are a lot of products like that, that I think ought to be banned right away.

Mr. IMBRECHT. I would suggest that should be a high priority because I do not think it is such a massive dislocation and you can say ban the manufacturer of CFC's and we have a sort of ticking time bomb out there that can go on for another 20 years, and we really have to come to grips with those emissions and——

Senator GORE. I think that ought to be done too, but I will come back to that on my time.

Mr. IMBRECHT. And just to expand on that a moment, that should also include some mechanism for cars that are going to be wrecked or permanently disabled for a recapturing strategy there. Some type of rebate or incentive, I would suggest the same thing for refrigerators that are being scrapped.

Senator GORE. Industrial cooling units.

Mr. IMBRECHT. That is correct. And we have undertaken incentive and rebate programs for our utility rate structure to encourage people to trade-out refrigerators on the basis of energy efficiency. It seems to me that there is a certainly an equally strong policy argument to do that on the basis of CFC emissions. So, if you are just looking for a single bullet that would be the one I would offer.

Senator WIRTH. Also, let me ask you, Mr. Imbrecht——

Mr. IMBRECHT. There is lots of other things that have to be done simultaneously, but you wanted just one, so that is——

Senator WIRTH. We have been somewhat frustrated at the—as I was suggesting earlier, at the response of the present national administration. The response has been very mixed. And, it seems to me that the country would probably be better off if the direction and the clarity with which you all in the State of California have been approaching energy policy and global environmental issues were somehow transmitted to the White House. Do you know if the Governor or have you ever been asked by the White House for any input or advice or perspective on what you have done?

Mr. IMBRECHT. Yes. In fact, I just returned from Washington. I was there for most of last week, along with my counter-part, the Chairwoman of the California Air Resources Board which is sort of the parental agency, in a sense to South Coast, Jan Sharpless and we had extensive discussions at the very highest levels of the administration at all the relevant agencies, secretarial level down through the assistant secretary is probably as far down as we went. We also met with a wide range of staff people and so forth on the Hill and both Houses.

Senator WIRTH. Did you meet with White House staff people?

Mr. IMBRECHT. Pardon me?

Senator WIRTH. Did you meet with White House staff people?

Mr. IMBRECHT. Yes, we did. Yes, as well as OMB, as well as EPA and DOE. Twice, yes, twice in the White House and once with OMB.

Senator WIRTH. Well, that is encouraging.

Mr. IMBRECHT. And, I understand exactly what you are saying. Let me just offer—I try to look at the glass as being half full rather than half empty.

Senator WIRTH. So do we or we would not be in the business that we are in. Sometimes it looks like it is draining.

Mr. IMBRECHT. And, I detect a very remarkable change in philosophy on all of the topics that I discussed in my remarks, from conservation through alternate fuels to general awareness and sensitivity to emissions and environmental questions from where we were at say a year ago. So, I am very encouraged and I can—it is obvious that the battles have not been clearly won, but it seems to me that if I learn anything about counting votes, if you will, from the legislative days, there seems to be a real strong momentum developing.

So, I am—I want to encourage that and I want to compliment it and I will stay tuned to see if we ultimately see policies that reflect that. Let me offer just one observation. I think Secretary Skinner's decision to reject the waiver petition and allow CAFE to return to 27.5 after being stagnant for the past decade, is one of the clearest cut hard illustrations of the attitude that I am talking about that I have seen so far. We think that there ought to be a approach to CAFE somewhere the way we have approached the building and appliance standards with a regular cycle to be reviewing and plenty of advance notice so you are not impacting jobs and all of those other considerations, adopt—in our case for appliances, for example, we adopt now five years advance limitation so that the effected industries have more than ample opportunity to change their production lines and so forth, but it is a very, very firm adoption and it does take effect. We are trying to work with DOE on that very issue right now.

Senator WIRTH. Have you had—just to follow up on the meetings and who you have dealt with, have the feeling that the people in charge of this, Governor Sununu in the White House, Richard Darmen in OMB, have the two of them had the opportunity to hear the kinds of things that you are suggesting?

Mr. IMBRECHT. Well, we did not meet with either of them personally. But we probably came as close as we could have other than with them personally. We did meet with Mr. Darmen's deputy who is responsible in all these areas, and we met with Mr. Gray and a variety of other individuals that he invited to the meeting from——

Senator WIRTH. Mr. Gray has understood these issues for a long time. I really want to be quite specific because there is quite—as I understand it, there is quite a difference in perspectives and one of the things that it seems to me we want to do is to make sure that people who are perhaps as credible as you are, you know, coming from a Republican Administration in a state like this one—I mean, that is very important politically for the White House to—it is a lot easier for you to get in and to make that case than it is say, I suspect, for many of us who might be viewed as partisan or wanting to use this for political purposes or whatever it may be. But if you all are coming in and making that case, that is terribly important.

Consequently, the responsibility that you have to do this, I would say, not to load more on you than you already have, I would just urge you to continue those efforts, because I think it is enormously important to get this administration and all of the key people over what I would call the want to line, over the desire not to kind of resist it or not to view it with the inflexibility—that was the word that was used in the previous panel that we have often seen, but to be open to the fact that there are options that are available. There are real successes out here and that you can point to them as you did this morning so eloquently, one, two, three, four, five. And that we can than—that helps all of us on the Hill then to work with them.

Mr. IMBRECHT. Well, all I would say is that as I indicated, there has been a very water shed kind of change in attitudes on these issues. We were not invited to address them in the past and we were there at their invitation and insistence and specifically to discuss the widest range of issues associated with the national Clean Air Act legislation and the proposed administration legislation on that topic. So, I have to say that there was great reciprocity and I think that others in California have been called back as well. Secretary Sharpless' chief assistant, Jim Boyd, is an executive officer of the Air Resources Board made a similar trip a few weeks earlier. I think Dr. Lents has been there extensively. We have sent some of our consultants back as well for technical follow-up as a culmination of the meetings that we had last week.

I intend to be in Washington two out of the next three weeks and but for the fact that I still have to run an agency in California, Congressman Waxman and Lewis were very hopeful that I could come back to D.C. next week, but I——

Senator **Wirth**. We appreciate it. Thank you very much, Mr. Imbrecht. I'm going to come back to you Dr. Lents, but I have used more than my share of time. Senator Cranston?

Senator **Cranston**. Chuck, I would like to ask you just about your impression of the feasibility of the two ways of propelling automobiles other than by gasoline. One is compressed natural gas. The other methane and on that, I would like to ask about formaldehyde emission problem.

Mr. **Imbrecht**. Certainly.

Senator **Cranston**. Where do we seem to be on those two?

Mr. **Imbrecht**. Thank you. Well, with respect to CNG, we—contrary to some of the popular perceptions, we are very strong advocates of all three, methanol/ethanol, CNG and electricity. The last two for the foreseeable future, in our judgment, are likely to be nitch market applications CNG, for heavy duty buses and for fleets returning to central locations for refueling, et cetera, are in our judgment the most likely near term for the next 10 to 20 years. There is a long answer to that. How much detail do you want to go into, I will, but cost, infra-structure replacement, driveability, driving range, all those kinds of considerations suggest to us that it is not yet a mature technology for broad market penetration.

Methanol is obviously the most compatible to the existing supply and distribution infra-structure. You can pump it, tank it, truck it, et cetera, essentially like you can gasoline or diesel. So, it does not have that massive front end cost and dislocation that some of the others might if they were viewed as across the board.

On the formaldehyde side, probably the most interesting conclusion, at least from my perspective that came out of the Carnegie-Mellon study which was conducted under contract to the Air Resources Board, and was a very comprehensive modeling of the South Coast Basin, concluded that despite the fact that you have higher tailpipe formaldehyde emissions from methanol, because the reactivity of the methanol hydrocarbon is so much less, that was illustrated in Dr. Lents' slide that showed the ROG, that the atmospheric formaldehyde formation as a result of the photochemical process, is much, much less and that you end up with a net reduction in atmospheric formaldehyde.

Now, that is not to say that we should not still attack the tailpipe formaldehyde emissions. In fact the Air Resources Board has already adopted the first standard in the country to insure that formaldehyde emissions are down comparable with gasoline vehicles. And that is also our specifications for our demonstration vehicles.

But the good news is that even if we could not find a catalyst to deal with the tailpipe, we still are actually reducing civilian or population exposure to formaldehyde. I might say finally, that under any circumstance, the formaldehyde levels in the atmosphere are, I am told one one hundredth of that indicated by that medical community as being health impacting. So, not to be ignored, but at the same time, not nearly the problem that we or anyone else considered it potentially to be.

Senator **Cranston**. Jim, do you have anything to add to that or any different view?

Dr. **Lents**. The only thing that I would add to it, I think we are more optimistic again, depending upon the will of us here in California and the will of you in Washington, that electric technology can play and fuel cell technology can play a bigger and faster role over the next twenty years than Chuck was suggesting. But other than that, I think we are in total agreement. We think methanol is worth considering and it has the distinct advantage that allows us to transition very rapidly. There is no reason why every car built in the United States within a very few short years could not be flexible fuel and be able to use all of those fuels. And—but we think we need to transition beyond that in this basin toward even lower emitting vehicles either by improving the control technology on methanol vehicles beyond what we know today or making longer range, faster charging electric vehicles or fuel cell vehicles feasible.

Mr. **Imbrecht**. If I might just add on to that, I had a professor at Occidental that used to say, "Truth equals technology", and if that is the case, truth is changing very very rapidly with respect to vehicle technology. There are some very exciting things going on right now. They in fact, will even much more dramatically reduce methanol engine emissions. There are also some exciting things going on in electric vehicle technology with new batteries, longer driving range, et cetera. Similarly for CNG and all three areas tremendous advances.

On the electric side, the only cautionary note we offer is that if you talk about extremely large numbers of electric vehicles or essentially all the passenger vehicles in southern California, something of that nature, you have profound capacity requirements for the electrical system and just as we suggested, you need to internalize the externalities in other resource acquisition decisions, it needs to be done here clearly as well. We have to—before we embark on a path of all electric vehicles, we have to know what kind of plants are going to produce the electricity, where they are going to be located and what the environment implications of them are. Electric vehicles that are clearly recharged off peak, using spare capacity that is idle or in spending reserve during the night time hours, obviously make a great deal of sense, because there is no additional capacity requirement on the system and no additional environmental implications other than what you are burning in the way of fuel.

But if you get in the situation where you might have a lot of people recharging or essentially topping off their batteries, topping off their tank, every time they go home or every time they park their car at their business garage, et cetera, then we are not just talking about air conditioning giving us a summer daytime peak problem, but we are talking about cars doing it as well. And I just think we need to know a few more answers to those kinds of questions.

Senator **Cranston**. Thank you very much. Jim, I would like to ask you one further question. You emphasized in your testimony the linkage between global warming and clean air. Clean air legislation is being drafted in the Senate. We are going to try to pass a bill before too long. Do you have any specific recommendations as to what we should include in that legislation so that we do not exacerbate the global warming problem as we deal with the clean air problem?

Dr. LENTS. You are not going be able to deal with environmental problems in cities including Los Angeles if you do not deal with the automobile. And it seems like there is a lot of resistance if not on the Senate side, on the House side dealing with the automobile. And it is going to have to be done. And that, I guess, would be my single most important issue to urge you to look at and to support in the Senate as well as in the House, is very tough standards all around for automobile fleet.

Senator CRANSTON. Thank you very much. Chuck, I would just like to join in what Tim Wirth said about the importance of your trying to use the California story of success in so many points to convince the people in Washington in the Executive Branch to learn from what we have done here and apply it nationally.

Mr. IMBRECHT. Well, one final observation in that context. I was very pleasantly surprised to learn—I probably should have done my homework a little better—that Secretary Watkins is actually a native of Pasadena and is very, very familiar with all the problems of the San Gabriel Valley. He still has a lot of family there and so forth. And so when we sat down, I found him not only to be already convinced on many of these issues, but very knowledgeable about out unique problems in southern California as well.

Senator WIRTH. Secretary Watkins really wants to make changes in the Department of Energy in this area. He has two problems; one, the overwhelming emphasis at DOE is on the current problems that they have with the nuclear weapons production plant, all the problems that exist there, which are almost overwhelming.

Mr. IMBRECHT. Which also effect us in California as well.

Senator WIRTH. And the second issue that he faces is the fact that he has behind him a bureaucracy that is going very much the other direction from the ways in which, you have outlined and we ought to be going. And to turn that around is very difficult. I think he has been very very good on all of these discussions. We just have to get that message lower down and get him some more troops to help him out.

Mr. IMBRECHT. I got the distinct impression that he anticipates making significant rotational changes within the department. One of the questions he asked was how long we leave our program managers in the same position and I said, never more than five years and usually on three to four year basis. And we have some good people, but a change in assignment sometimes brings fresh perspective. And he suggested to me that a lot of people have been in the same positions at DOE not appointees and so for, but the program managers, you know, for a decade or more, and even coming from their predecessor agencies.

If he is able to do that, I think we might see some changes.

Senator WIRTH. Albert?

Senator GORE. Yes, thank you very much. First of all, as you have noted, Senator Wirth, Dr. Lents is a native Tennessean and I am proud to be with you. And I believe your top assistant or chief of staff is a Tennessean also, Mr. Imbrecht.

Mr. **Imbrecht**. That is correct.

Senator **Gore**. And the official who accompanied you to the White House, Dr. Jan Sharpless is also a Tennessean and was on my personal staff a few years ago. I wanted to pursue the line of questioning that Senator Cranston initiated with regard to the interplay between clean air and the global climate change problem. California uses so little coal it may be an unfair question, but do either of you have a view of the—of the arguments some make that some of the mandated scrubber actually result in more CO_2 per ton of coal put into the atmosphere as the sulfur is pulled out.

Dr. **Lents**. I think it is true that with some of the air pollution control technology there are energy penalties. Therefore, you are correct, it takes a little energy to operate the equipment, therefore, requires more energy be put into the system resulting in some more carbon dioxide production.

Senator **Gore**. Well, we are going to have to clean the sulfur out anyway, but we do need to look at these impacts as we are designing a strategy for coping with them. Now, just looking at California's relationship to the greenhouse effect, you noted, Mr. Imbrecht, that California has less CO_2 for electrical generation than the rest of the country by quite a bit. It is also true that you have more in the transportation sector. Is that correct?

Mr. **Imbrecht**. Absolutely. Yes, it is.

Senator **Gore**. Now, when you look at the other greenhouse gases, CFC's, how does the per capital CFC contribution rank here as compared to the country as a whole? Do you know?

Mr. **Imbrecht**. I think it is quite well indexed to population. We do not see any abnormal consumption patterns in the other areas.

Senator **Gore**. Even with all the chip cleaning and all of the automobile air conditioning? Have you seen the figures or do you——

Mr. **Imbrecht**. Yes, I have seen the figures and it is essentially. It is not one of the areas we called out as a problem area because you have air conditioning now pretty much standard equipment throughout much of the United States with the exception of a few of the smaller northern tier states that are cool. So there—in our judgment at least, at this point, we do not see any—as I say, disparities between California CFC consumption other than maybe more hair spray. I do not know. That is a facetious comment.

Senator **Gore**. With the chip cleaning work underway——

Mr. **Imbrecht**. Oh, I am sorry, the chip cleaning, you are absolutely correct, we do use more CFC's there.

Senator **Gore**. Yeah, all right. Now, what about methane?

Mr. **Imbrecht**. I do not have that off the top of my head, but I do not think that it is substantially different.

Senator **Gore**. Well, one of the impacts may well be on agriculture—will be on agriculture and with California being our number one agricultural state, a serious effort to get at the greenhouse problem is going to have——

Dr. **Lents**. I would like to interject in that it was not probably five years ago that we, as an agency, was encouraging conversion to CFC's to clean chips or whatever, to get away from—because they are not considered a reactive hydrocarbon. So, again it is where there is a break in the linkage of air quality issues.

Senator **Gore**. Mr. Chairman, that concludes my questioning. I would like to thank the panel.

Senator **Wirth**. Thank you very much. If you all would like to wait and we will come back to questions, we have been joined by Mr. Robert Redford, and Mr. Redford, maybe you could come up and join us, if you would do that. We realize that you have a plane to catch very shortly and we greatly appreciate your coming by and sharing with us your thoughts and perspectives on this important issue of global environmental change. As I think everybody here knows, Mr. Redford, on his own and through the very valuable contributions of the Sundance Institute in Utah, has been out in front of a number of environmental issues and has taken this one on. We had dinner together in Denver about six months ago and we were looking at various joint agendas that we might take on and I asked Bob if he would like to come by and share some thoughts with us today, and he very kindly said that he would. We are delighted to have you here and greatly appreciate it.

Please proceed in whatever way you think would be most appropriate. We have had a fascinating morning of inputs from a lot of the scientific world and now the governmental world, and we are so pleased to have you here. Thank you very much for joining us.

STATEMENT OF ROBERT REDFORD, SUNDANCE INSTITUTE, SUNDANCE, UT

Mr. **Redford**. Thank you for inviting me. Senators Cranston, Gore, hello. Well, I am a native of southern California. I was born and raised here in Santa Monica, grew up here in the San Fernando Valley. And for decades I have watched this area change, where it was once a beautiful clear place, where nobody ever thought about air pollution because it was not a problem. And I watched through the years, this incredible transformation take place as visibility and breathing and just moving became so difficult that the very reason that people came here was slowly shattered.

So, I am here today because not only of a long-standing concern for the environment, but the issue of global warming being so important. It represents a great deal of work for me that really began in the early 1970's. Work on the Clean Air Act, the Energy Conservation and Production Act, strip mining legislation and the promotion of solar and other energy alternatives; all issues that I have been deeply committed to over the years.

So, I began to build an organization which reflected that concern for the environment and it is called the Institute for Resource Management and the IRM got underway in 1983 with a series of conferences to address the environmental issues deadlock by opposing sides. And these issues have ranged in our history with the conferences from the future of the electric utility industry to resources on Indian lands, offshore leasing in the Bering Sea of Alaska, the ten year master plan for the Forest Service for the next ten years and finally, as you know, Senator Wirth, the conference in Denver on clean air that we held a year and a half ago.

And at the Denver conference, the players that were there included Congressional, State and local representatives from several metropolitan areas. There were medical experts and alternative fuel experts, oil company executives and environmental leaders. And there were several disturbing and also moving moments in that conference. At one point the Mayor of Phoenix, Terry Goddard stood up and he said to the representatives from Denver, Salt Lake and Los Angeles, "Look, you guys, we all have something in common here. We all represent cities that people came to through the years for their health. And now what we have is irony. My city, like yours, is a place that is polluted". He says, "People are dying". He says, "I have a lynch mob mentality and people are expecting me to lead them". And he says, "I don't have enough information. Please help me".

Now, the most disturbing moment in the conference was when, in response to a lot of questions—there were a whole lot of questions about the issue of the greenhouse effect, global warming and it got so intense that finally there was a presentation made by a representative from the National Center for Atmospheric Research in Boulder in response to this. And it was a very graphic slide show and documents that presented staggering evidence that there were real significant dangers of global warming but it was very specific, it was very clear and there is no longer any danger that this was something that was coming. It was here.

So, it was clear that this information had been in the scientific community in the halls of science as dialogued among scientists for a long time, in fact, too long and it was time to get it out to the public. So, that prompted us to center our next conference around the issue of global warming and the climate change.

And a subsequent trip to the Soviet Union that I took last May produced further surprising information. I had the opportunity there to co-chair with the President of the Soviet Academy of Sciences a meeting in Moscow of Soviet and American scientists to address the issue of the greenhouse effect. And we found out that many of the Soviet scientists were agreeing with ours and were coming up with precisely the same set of facts.

We also learned that the Soviet people have a very passionate and deep concern for their land. So, an agreement was signed by the IRM and the Soviet Academy to work together on the climate change issue. So, the first major step in implementing that agreement is going to be a conference at Sundance, Utah in August, a gathering that is going to include public policy makers, scientists and artists. And it is going to be an attempt to move this issue of climate change forward by proposing specific actions to be taken and this is probably the most important part of the conference and the greatest contribution that we can make to the overall issue is to get that information out to the ones who need to know, the people of both countries and the world public at large.

I tell you all this as background to explain how my involvement in environmental issues has led to my testifying here today. And as you are obviously hearing in today's testimony, scientists are telling us that the results of our activities are causing a global warming of three to eight degrees fahrenheit and it is likely that we will also see an increase in forest fires, heat waves, droughts and flooding. Carbon dioxide levels have increased by 25 percent since the beginning of the Industrial Revolution.

The concentration of other harmful gases are also reaching alarming levels and these gases have been loaded into the atmosphere over the years with good intentions. We have all contributed to the current problem in our quest to improve the quality of our lives with our cars and our fertilizing, our home appliances and reliance of fossil fuels. But what we have lost sight of is that the quality of our environment is directly connected to the quality of our lives.

And like in February, it was reported that California was headed for its third consecutive year of drought, something experts say has not happened since the sixteenth century and just last month, we had six days of record-breaking temperatures over a hundred degrees. So, I believe that we know enough to act. And the sooner we start, the more of a chance we are going to have to alter this warming trend. Many people say we are beyond the correction stage, that we can only look to adjustment or alteration as any kind of a solution and that the action that we can take to delay climate changes are actions that we should be taking anyway, reducing our reliance on fossil fuel. That is not new. We have been hearing that for a long time. Promoting alternative renewable energy supplies, that is not new. We have been hearing that for a long time.

Developing cleaner more efficient technologies, phasing out the production of CFC's and stopping deforestation. Years ago when these issues first emerged, scientists warned that people would suffer, that ecosystems would suffer. And they were right. But, nobody was listening. And many people denied the problem. And unfortunately too many of the people denying the problem were people who were in corporate or government leadership positions. So, the meter ticks. It seems clear to me that what we must do is to find a balance between what we are going to preserve for our survival and what we are going to develop for our survival, the urban pollution, the Valdese tragedy, global climate change, they are all symptoms of a failure of our political system to come up with a national energy policy.

And consequently energy efficiency is not a priority. Alternative energy sources like solar and wind are not taken seriously or have not been taken seriously until possibly right now, when right here in California, there are positive—as Senator Cranston knows, right here in California there are positive working examples of these technologies. Now, if we can stop looking at the concern for the environment as something that impedes progress but instead look at alternative energy sources as a form of production, then economic development can be gained from switching to other technologies.

In the area of energy efficiency, we are way behind other countries like Japan and West Germany. Our country had better start dealing with these facts if we want to take a leadership role. And as we have been hearing over and over again in the last while, particularly recently, there are a lot of people looking to this country to do just that. So, how ready are we? How qualified are we, because what we are talking about here are global issues and are we a global leader? Are we a global player or not?

If we allow our own indiscriminate ways to go unchecked in favor of short-term profit and greed as we have just sadly seen in the case of the Exxon oil spill, then we are going to be responsible for destabilizing the planet and the whole balance of power is going to be affected. The causes of climate change are international. Together the USSR and the U.S. produce more than half of all the greenhouse gases. In Brazil, the equivalent of one football field per second is being destroyed by burning. So, not only are trees, which recycle the carbon dioxide are being lost, but the burning releases additional carbon dioxide into the air.

We have in China a nation of a billion people, one-fifth of the world's population, is about to embark on a massive development of coal resources. At what price? We have learned a lot about what the burning of coal does to the atmosphere, and the ozone. There is a phrase in Niger. The peasants are heard to say, "La boo eeoo" which means the land is dead.

World-wide more than ten million acres of land turn to desert every year. The countries in the developing world seem to live on the amount of energy that we waste. So, it seems to me that the environment is an ideal place to find common ground among nations who have been struggling with each other for too long. International cooperation like we have never seen before is going to be necessary to deal with the problems of climate change. Now, these issues, in my opinion, are far too important for traditional adversaries to line up on opposing sides as they have for years.

And it is too urgent to wait for the normal ten to twenty years before scientific developments are integrated into mainstream thought and action is finally taken. Our environment has really been pushed to the breaking point. All this talk about frontiers, there are none. There are no new frontiers unless we are going to be talking about space. If we are not careful, we are, I think going to become nature's victims instead of nature's beneficiaries. So, we are at the point where we cannot separate it out. We are all in it together. Unfortunately, until now, we have been subjected to a mentality about the environment that has been old-fashioned, outmoded and in some cases, just plain mean spirited.

We must recognize that we are beyond that and we cannot continue with held over positions that still regard the environment as the enemy or are worried that the petroleum industry is going to be threatened. I do not believe that we can hear any longer that we have to wait and see, that we cannot hear any longer that we need more information, that we need to move slowly because the facts are not in. We have to appoint committees to study feasibility charts and so forth and so on. I do not believe we need to hear that any more; that we know enough to act. And the need is to act quickly. And there are enough facts, there is enough consensus by credible respected experts to begin and the power and push and pressure from the people is beginning to come on real strong. So, we are moving if not already, at a crux.

It is time that the environment be raised, in my opinion on our national list of priorities to the level of national security, because if we poison our land and our air and our water, what is there going to be to defend? And what indeed have we left behind for our children? So, it is time to take action. I urge that action. I support and congratulate you on hearings such as this. And, the National Energy Policy Act of 1989 is a very good place to start. Thank you.

Senator WIRTH. Mr. Redford, thank you very much. I know how tight your time is. Do you have time for a couple of questions, if we might?

Mr. REDFORD. Sure.

Senator WIRTH. You said in your testimony it is far too important for traditional adversaries to line up in a traditional way. And it seems to me it is far too important as well, for us to kind of follow traditional modes of educating constituencies. You said that the power of the press is now coming from the people. The concern is there. I am not sure that we are there yet. I am not sure that we are at a point where there are enough constituencies out there, you know, in this democratic society that when you get out front you start to make these initiatives and take these steps and do the very brave things that are being suggested here in southern California and elsewhere that it is going to happen without a greater awareness. One of the items that I find myself increasingly concerned about, the more I get involved in this, is how do we go about globalizing public opinion, you know, in a Democratic society? You know, how do we get to 235 million Americans to get them—or a majority of them, or a greater number of them to understand the size and scope of this?

It seems to me that, you know, we have to—this is not a traditional education program. We do not have a generation of kids to go through school. We do not have time to do that. We do not have time to wait until the crisis is there absolutely and the lights start to go out or environmental systems break. And the gap, the sense of urgency that the more you know about this, the greater a sense of urgency you feel. How do you get that transmitted to—in a Democratic society to constituencies who have to understand this, not only in the United States but in Europe and Japan and elsewhere?

Mr. REDFORD. Well, I agree with you, Senator, that that is a serious problem. I think probably when you have a failure of leadership at the top, you resort even more strongly to the Democratic system. And, it is my opinion that things are changing very rapidly. The environment, thank God for all of us that have been working so long, is beginning to take on almost a fashionable element. The fact is, it is becoming important to a lot of people and I think it is becoming important because the crisis has landed in their own backyards. I mean, it is affecting people on the human level. It is affecting us on the human level. When that happens, I think you begin to get pressure. So, I think the problem has been that the information that we are now hearing has been information available pretty much for 10 years, but what we have had is, "Well, we are not sure. Is it going" to—for example, the new information on ~~flooding~~ that is coming out, the rising temperatures are increasing the level of the sea.

Okay, well, before it was, "Well, in some places, yes, in some places no." So, you have this debate going back and forth that stalled out the issue. Now, there is enough known, there is enough fact to make us move into action. What I think needs to happen, since the concern is there from the people's standpoint, and now the concern is growing because of the political pressure of the people's standpoint, I think it is up to certain areas of our society to do what they can. And in my case, it seems to me it is in my own profession if it is responsibly undertaken, to get the word out that has existed in the halls of science for so long, get that word out to the people so they can start generating the pressure for political leaders and policy makers to act. And that was the reason for our conference in August, is to bring—rather than just have scientific—which are very valuable—rather than to just have the scientific conferences that restate this information and tend to recycle it, get it out to the public and have a conference that is going to involve the policy makers who can effect action, can put it—and force it into legislation and to people who are artists who can communicate. That is our business, communication. So, it has to be communicated to the public and policy makers have to begin to put this into action.

So, I feel that hearings such as this and the work that you have done, Senators Gore and Cranston, are very valuable for the public on the community level. I have always believed that. I have always believed in grass roots efforts. And that work like this on a community level that just builds steadily is certainly one way to do it. So, the combination of what possibly somebody like myself can do in my profession, what you are obviously already doing, is a start. I agree with you that it is not enough. I agree with you that we are not there, but I am somewhat optimistic that it is starting.

It just has to happen quickly. When the facts are as evident as they are, then it just stands to reason that we have to move fast.

Senator **Wirth**. Alan?

Senator **Cranston**. I do not have any questions. I would like to thank you for your very, very fine testimony and more for the leadership and the willingness to bring your resources and your capacities to bear on this tremendous problem. It is just marvelous you are doing that. And I am particularly delighted that you are working with people who share these concerns in the Soviet Union, because the more we two countries can find ways to work together, the more we can overcome our problems and reduce the danger that a stupid conflict between us could wipe out the human race.

Mr. **Redford**. Well, thank you. So this does not turn into, you know, your turn to curtsy, my turn to bow deal, I would like to compliment you on what has happened with the state, my native state. It started out being the leader of negative statistics. I watched it happen, but I am also happy to see that the state with the biggest problem has done probably the most to correct it and turned itself from being a liability to a possible model for what other states can do for the future. I am thinking specifically about Salt Lake. I mean, they had better pay a lot of attention fast, because they are heading right for the place Denver went to and so forth.

So, I congratulate you.

Senator **Cranston**. Thank you.

Senator **Wirth**. Albert?

Senator **Gore**. I do not have any questions either, but I would like to echo Senator Cranston's comments. It would be awfully easy for someone as popular as you are and as absorbed in the movie making business as you are to just wash your hands of public policy and not worry about it, but you have not only worried and gotten yourself involved, you have done it in a very substantive way and I do not want to, you know, flatter you for the sake of flattering you, but I go to a lot of conferences and a lot of meetings and the way your institute designs them, pays a great deal of attention to the substance and to the science and the policy and I think that is a real contribution that you make to this country and this world.

And like Senator Cranston, I think the relationship with the Soviet Union is particularly important. Senator Wirth and I were with some of the Soviet environmentalists this past summer at a conference and this fall I am going to China and am in the midst of a project that is designed to try to draw out some possible alternatives for this tremendous increase in the burning of coal that you referred to in your testimony, because even if we are spectacularly successful in the developed world, if we do not find a way to change the technologies now available for economic development and growth in the third world, particularly countries like China, then they could completely wipe out all of the gains and progress that we make on our part.

I do not think we need a strategic defense initiative. I think we need a strategic environmental initiative to really focus effort and resources on the development of new technological processes that can allow us to escape this terrible tradeoff. We have a Hobbesian choice now between economic growth or a clean environment. And we have to change that because the third world will not accept a path that calls for stagnation. Stagnation for them means that whole populations are engulfed in starvation and epidemics and we really have to change the terms of the tradeoff.

I look forward to the conference in August and again, I really appreciate the work that you do in this area.

Mr. **Redford**. Thank you very much.

Senator **Wirth**. Okay, well, thank you all very much. We have come to the hour that was promised the Santa Monica and the Los Angeles School District to be out of here at 2 o'clock, and it is now 2 o'clock. My apologies to all those who waited around for the purpose of asking questions but time has just rolled along in a—I thought just a wonderful morning of testimony and thought and information and certainly very helpful to us in making the record.

Dr. Lents and Mr. Imbrecht, we want to thank you also for the very clear direction which you all are setting here in California. It is extremely impressive to see what you are doing and I hope that we are able to transmit that more broadly across the country. To our three earlier scientific witnesses, Dr. Schneider, Dr. Gleick and Dr. Dracup, we so appreciate your great work and that is the underpinnings that allow us to move ahead in the way that I hope we can in the United States Senate and certainly has been done here in California. And to Robert Redford, we thank him again for being with us and helping us to outline, understand and underscore the importance of this issue.

I want to thank Senator Gore, as ever, for being my partner in this and so many other issues related to global environmental issues. I think we are making some progress and we just have to accelerate that and get up the curve of progress as rapidly as we are going up the curve of environmental degradation. And Senator Cranston, as ever, you have been a leader for all of us in every possible way as an American political figure, as a conscience of the Senate and as an individual who understands that we must think about the future. To all of you, thank you very much for coming. We deeply appreciate your being here and particularly on such a remarkably beautiful afternoon to come out and spend your time on an issue like this.

All of you, thank you very much; this subcommittee is adjourned.

[Whereupon, at 2 p.m., the hearing adjourned.]

[An additional statement submitted for the record follows:]

Zond

BRIEFING TO THE COMMITTEE ON ENERGY AND NATURAL RESOURCES

CALIFORNIA WIND POWER: REDUCING AIR POLLUTION AND GLOBAL WARMING WHILE ENHANCING ENERGY SECURITY

- A MODEL FOR AMERICA -

BY JAMES G.P. DEHLSEN
CHAIRMAN AND CEO
ZOND SYSTEMS, INC

CALIFORNIA WIND POWER:
REDUCING AIR POLLUTION AND GLOBAL WARMING WHILE ENHANCING ENERGY SECURITY

-A MODEL FOR AMERICA -

Deteriorating environmental conditions and increased vulnerability to disruption of energy supplies provide compelling reasons for renewed emphasis on wind energy development.

The purpose of this testimony is to present summary data on the contribution which California's wind power industry has made to reducing air pollution and global warming, and to the enhancement of energy security (Table I). The paper also presents the potential contribution to California, by the year 2000, assuming additional turbines are installed sufficient to meet an additional 5% of the State's electricity needs (Table II). Summary data is also provided in Table III for a typical state-of-the-art wind power facility.

Further development of California's wind resource, when compared to most thermal generation alternatives, should prove to be among the most competitive, reliable and environmentally compatible choices available in the 1990's.

In the United States, there are a total of thirty-seven states which have areas of commercially viable wind resource. Based on wind development experience in California in the 1980's, and the advanced wind power systems now available, with a state and federal committment to renewable energy in the decade ahead, wind power could achieve a 3.4% contribution to the nation's electricity requirements.

This additional wind power generating capacity would not only provide more cost competitive power for 120 billion kilowatt hours per year (the energy equivalent of 200 million barrels of oil per year), but also abate the emissions of over 145 million tons per year of carbon monoxide, over 3% of the total annual produced by fossil fuel combustion in the United States.

TABLE I

SUMMARY 1988

CALIFORNIA WIND POWER

Operating Data

Turbines operating	17,000
Availability	95%
Kwh generated - 1988	1.8 Billion (approx. 1% of CA use)
Equiv. residences/population	300,000/1,000,000

I. Environmental Benefits	"BEST CASE"	"WORST CASE"
AIR POLLUTION ABATED	AQMD(1)	COAL(2)
Criteria pollutants - tons/yr	1370	62,000
Annual Benefit - in Millions	$24.5	$327.2 (3)
Benefit - cents per kwh	0.014	0.181
GLOBAL WARMING CHEMICALS ABATED - tons/yr		
Nitrous Oxide (150 year life)	1035	1890
Carbon Dioxide (500 year life)	990,000	
Forest equivalancy (4)	41.2 Million mature trees	
Benefit	not determined	

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(1) Based on AQMD BACT values - assumes only natural gas combustion displaced- see Exhibit A.

(2) Assumes displacement of out-of-state coal fired generation.

(3) Proportions 62,000 tons to AQMD's Tier I annual reduction of 1.8 million tons with resulting percentage applied to $9.5 billion annual value of benefit. This is an arguable approach but provides an order-or-magnitude estimate.

(4) Assumes CO_2 fixing of 48 lbs/tree/yr.

II. Energy Security

Thermal equivalent - bbls of oil	
Per year	2.83 Million
30-year contract life	85 Million
	Annual wind production now equal to one day of sustained draw-down of U.S. Strategic Reserves
Military costs	none
Balance of payments deficit	none
Energy supply interruption costs	none

III. Other

Health Benefits - Death incidence of air pollution-related lung disease (30 year contract life)	600 lives
Transportation infrastructure	none
Water use avoided vs. steam generation	2880 acre ft/yr
Operational risks	minimal
Waste disposal	none
Decommissioning costs	minimal

EXHIBIT A

ESTIMATES OF AQMD BENEFITS

The value of the clean air benefit for the Gorman Wind Project is based on SCE's combustion of natural gas only for power generation displaced by the wind project. This data was extrapolated in Tables I and II to provide the wind industry benefit for emissions abatement.

Clean Air Benefits - Value of the Gorman Wind Project

Assumptions:

- Edison Burns Natural Gas rather than Fuel Oil
- Projected Output of Gorman = 200,000,000 kwh
- Value of Avoided Emissions = BACT $/ton as of 10/87
- Marginal Resources for SCE: Oil & Gas 85% of the year (3)
- SCAQMD Rule 1135 Fully Implemented by 2000

Output: 200,000,000 kwh/year

Pollutant	lbs/1000 kwh Factor (1)	Lbs/Yr	Tons/Yr	Value/tn (2)	Value/Year
CO	0.2	40,000	20	N/A	0
NO_x	1.2	240,000	120	24,500	2,940,000
ROG	0.01	2,000	1	17,500	17,500
SO_x	0.12	24,000	12	18,300	219,600
Particulates	0.04	8,000	4	5,300	21,200
Totals		314,000	157		$3,198,300

Corrected for Time Oil & Gas is the margin: 85%	$2,718,555
Benefits for 1st 10 years	$19,075,105
Benefits for next 20 years	$14,803.600
Total Benefits	$33,878,705

Sources:

(1) South Coast Power Plant Emissions Factors - 1986
(2) South Coast BACT values in Letter from Lents to Board, dated 10/27/87
(3) MRW Testimony in SCE Rate Case #86-12-047 (4/87)

YEAR	FACTOR	TONS	NOX $$	OTHER $$	TOTAL $$
1990	1.20	120	$2,499,000	$219,555	$2,718,555
1991	1.11	111	2,311,575	219,555	2,531,130
1992	1.01	101	2,103,325	219,555	2,322,880
1993	0.92	92	1,915,900	219,555	2,135,455
1994	0.82	82	1,707,650	219,555	1,927,205
1995	0.73	73	1,520,225	219,555	1,739,780
1996	0.63	63	1,311,975	219,555	1,531,530
1997	0.54	54	1,124,550	219,555	1,344,105
1998	0.44	44	916,300	219,555	1,135,855
1999	0.35	35	728,875	219,555	948,430
2000	0.25	25	520,625	219,555	740,180
				TOTAL	$19,075,105

TABLE II
PRO FORMA YEAR 2000

CALIFORNIA WINDPOWER
ASSUMING 5% NEW PENETRATION

Operating Data	TURBINES INSTALLED AFTER 1989	
Turbines	10,000	
Average size	400 kw/36 m. rotor	
Electricity generated	10 Billion kwh per year	
Land area required	74,000 acres (30% size of Edwards AFB)	
Estimated acreage affected (roads, pads, etc.)	10,000 acres	
Environmental costs	minimal	
I. Environmental Benefits	"BEST CASE"	"WORST CASE"
AIR POLLUTION ABATED	AQMD	COAL
Criteria pollutants - tons/yr	7,600	344,000
Annual benefit - in Millions	$136	$1,800
Benefit - cents per kwh	0.014	0.181
GLOBAL WARMING CHEMICALS ABATED - tons/yr		
Nitrous Oxide (150 year life)	5,740	10,490
Carbon Dioxide (500 year life)	5.5 Million	
Forest equivalancy	230 Million mature trees	
II. Energy Security		
Thermal equiv. Bbls. of oil		
Per year	15.7 Million	
Contract life	470 Million	
III. Other		
Water use avoided vs. steam generation	16,000 acre ft/yr	

TABLE III

KEY FACTS
THE GORMAN WINDFARM

Size	Capacity	77 megawatts
	Turbines	458
	Electricity generated	180-200,000,000 kwh/yr
	Residences (equiv.)	35-40,000
	Project cost	$85 million
	Employment	
	Construction	60 people - one year
	Operation	15 people - 30 years
L.A. County - Fiscal	Property tax revenues	$850,000/year
	County Services	Minimal required
Pollution Abatement	The project abates utility fuel combustion, emitting (1)	
		Pounds/year
	Sulfur Oxides	24,000
	Nitrogen Oxides	240,000
	Carbon Monoxide	40,000
	Particulates	8,000
	Reactive Organic Gases	2,000
	TOTAL	314,000
	This amount of abatement - 157 tons per year - is equivalent to reducing emissions by one third for over 18 "major" point source polluters	
	Value of Benefit(2)	$33.8 million over 30 year life
	Carbon Dioxide Abatement (3)	220 million lbs/yr
	Equivalent number of mature trees (4)	4,580,000
Environmental Impacts:	Visual (5)	slight
	Biota	insignificant
	Erosion	mitigatable
	Sound	insignificant
Health Benefits	Death reduction due to air pollution health risks (6)	30 lives (over 30 years)

Water use avoided vs. steam generation		320 acre feet/year
National Security Benefit	Reduced oil imports(7)	964 barrels/day 10 million Bbls/30yr (Equiv. to 2% of current Strategic Petroleum Reserve)
	(8)	No expenditures for military force
		No economic disruption due to interruption of oil supply
Balance of payments benefit	Reduced outflow (1989 dollars) for oil purchase (9)	$350 million (30 years)
State/Federal Subsidies	(10)	none
Transportation infrastructure required		none
Risk of fuel spills		none
Hazardous waste disposal	(11)	none
Operational risks to Community (ie., radioactive contamination, etc)		none
Decommissioning cost		minimal
Consumer preference	1989 CA Survey of attitudes toward Biomass, nuclear, fossil fuel, and windpower plants(12)	Visual quality: most attractive Public health & safety: safest Environmental damage: safest Acceptability: highest
Other Environmental and Social Benefits	Formed the Meritus Foundation to assist local environmental and social programs	Annual contribution by the Windfarm: $120,000

REFERENCE INFORMATION

1. Pollution Abatement Benefit
See Exhibit A.
2. Value of Benefit
Derived from 1989 Air Quality Management Plan; South Coast Air Quality Management District. See Exhibit A.
3. Carbon Dioxide Avoided
Based on data supplied by the World Resource Institute, and Dr. William Farone.
4. Equivalent Number of Trees
Assumes a mature tree will process (fix) 48 pounds of Carbon Dioxide per year.
5. Environmental Impacts
Based on findings in the Environmental Impact Report on the project submitted to Los Angeles County.
6. Health Benefits
Estimate is based on studies by the Biomedical and Environmental Assessment Division of Brookhaven National Laboratory.
7. Reduced Oil Imports
The estimated production of the facility - 200 million kwh/yr - would require 352,000 barrels of oil per year for equivalent thermal generation.
8. Military Protection
The Persian Gulf oil supply requires U.S. Armed Forces protection estimated by former Secretary of the Navy, John Lehman, to cost $40 billion per year. When that amount is divided by the 330 million barrels which the U.S. imported in 1986 it adds $121 of hidden cost per barrel. Persian Gulf Oil will be the predominant U.S. supply source in the 1990's.
9. Balance of Payments Benefit
Assumes a 30-year average price of oil of $35 per bbl multiplied by 10 million barrels displaced over the life of the project. The benefit will be ever greater as oil prices rise.
10. State and Federal Subsidies
Windpower production receives no subsidies as compared to nuclear energy, which when all forms of subsidy are accounted for, amounts to over 20 cents per kilowatt hour, according to studies by the Rocky Mountain Institute.
11. Hazardous Waste
Thermal power generation produces various types of waste - ranging from hazardous substances accumulated in air pollution control systems (scrubbers, etc.) to highly lethal, long lasting radioactive waste from nuclear generation. Windpower produces no waste.
12. Consumer preference
Based on the 1989 Report of a survey conducted by Dr. Robert Thayer, University of California at Davis.